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The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

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2.	William Clift	1872-1873	Albany, N. Y.
3.	William Clift	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877[1]	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
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14.	Theodore Lyman	1884-1885	Washington, D. C.
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20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
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31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.
35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va.

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[1] A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

36. E. A. Birge	1906-1907	Grand Rapids, Mich.
37. Hugh M. Smith	1907-1908	Erie, Pa.
38. Tarleton H. Bean	1908-1909	Washington, D. C.
39. Seymour Bower	1909-1910	Toledo, Ohio
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48. M. L. Alexander	1918-1919	New York, N. Y.
49. Carlos Avery	1919-1920	Louisville, Ky.
50. Nathan R. Buller	1920-1921	Ottawa, Canada
51. William E. Barber	1921-1922	Allentown, Pa.
52. Glen C. Leach	1922-1923	Madison, Wis.
53. George C. Embody	1923-1924	St. Louis, Mo.
54. Eben W. Cobb	1924-1925	Quebec, Canada
55. Charles O. Hayford	1925-1926	Denver, Colo.
56. John W. Titcomb	1926-1927	Mobile, Ala.
57. Emmeline Moore	1927-1928	Hartford, Conn.
58. C. F. Culler	1928-1929	Seattle, Wash.
59. David L. Belding	1929-1930	Minneapolis, Minn.
60. E. Lee LeCompte	1930-1931	Toronto, Canada
61. James A. Rodd	1931-1932	Hot Springs, Ark.
62. H. S. Davis	1932-1933	Baltimore, Md.
63. Fred A. Westerman	1933-1934	Columbus, Ohio
64. E. L. Wickliff	1934-1935	Montreal, Canada
65. Frank T. Bell	1935-1936	Tulsa, Okla.
66. A. G. Huntsman	1936-1937	Grand Rapids, Mich.
67. I. T. Quinn	1937-1938	Mexico City, Mexico
68. Fred J. Foster	1938-1939	Asheville, N. C.
69. T. H. Langlois	1939-1940	San Francisco, Calif.
70. James Brown	1940-1941	Toronto, Canada
71. John Van Oosten	1941-1942	St. Louis, Mo.
72. John Van Oosten	1942-1943	(No meeting)[2]
73. John Van Oosten	1943-1944	(No meeting)[3]
74. John Van Oosten	1944-1945	(No meeting)[3]
75. John Van Oosten	1945-1946	(No meeting)[3]
76. Joe Hogan	1946-1947	St. Paul, Minn.
77. H. H. MacKay	1947-1948	Denver, Colo.
78. Seth Gordon	1948-1949	Atlantic City, N. J.
79. Milton C. James	1949-1950	Winnipeg, Manitoba
80. Albert S. Hazzard	1950-1951	Ann Arbor, Mich.

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[2] The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.

[3] No annual meeting scheduled because of the war.

In Memoriam

●

Henry A. Larsen, Hayward, Wisconsin
Sherman C. Bishop, Rochester, New York
R. B. Cooper, Des Moines, Iowa
Thayre McCutchin, Madison, Wisconsin
Lewis Radcliffe, Washington, D. C.

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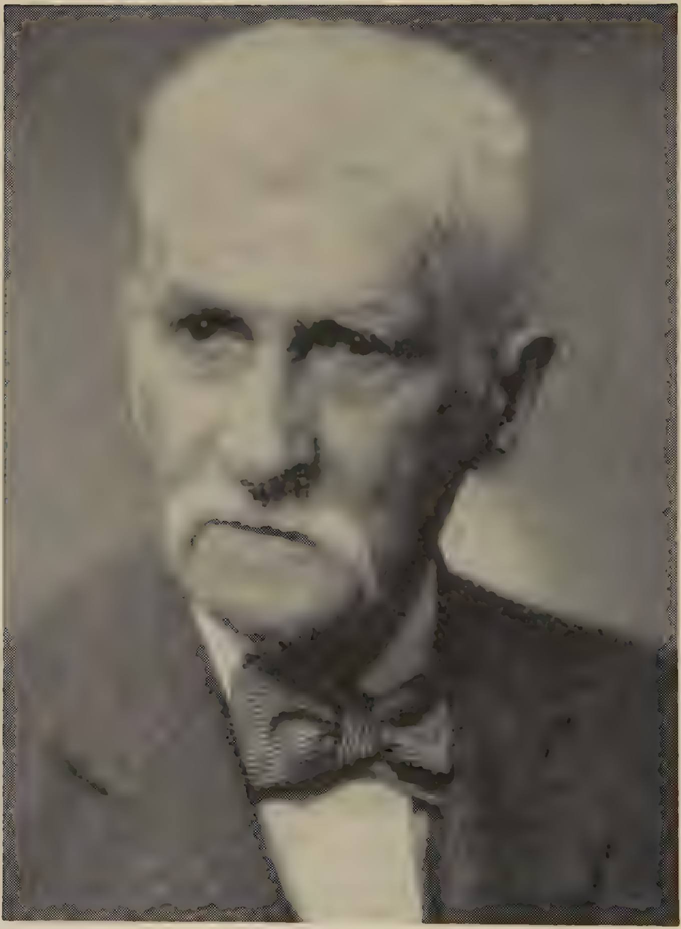

Edward Asahel Birge
(1851-1950)

EDWARD ASAHEL BIRGE[1]
(1851-1950)

Dr. Birge was born in Troy, New York, on September 7, 1851. He died in Madison, Wisconsin, on June 9, 1950, in his ninety-ninth year. He served as President of the American Fisheries Society in 1906-1907 and was a life member since 1897. He had a long and distinguished career both in teaching and research. He began teaching at the University of Wisconsin in 1875, holding the B.A. and M.A. degrees from Williams College. In 1878, he received his Ph.D. degree from Harvard. Dr. Birge was promoted from instructor to professor in 1879. After serving as head of the zoology department he was made Dean of Letters and Science in 1891. From 1900 to 1903 he was acting president of the university, and president from 1918-1925, and president emeritus from 1925 to 1950. From 1895 to 1915 he was a Wisconsin commissioner of fisheries and thereby was able to give the people of the state a direct application of the results of his researches.

The tremendous burden of teaching and administration seemed to stimulate Dr. Birge's interest and activity in research rather than to hinder his efforts. He began work on the Cladocera about 1875 and published several papers on this subject. His best known work in this field appears as a chapter in Ward and Whipple's *Fresh Water Biology*. In 1900 he brought C. Juday to Wisconsin to assist in research on the Madison lakes, thus forming a research team that brought Wisconsin world-wide fame as a limnology research center, and they worked together until the death of Dr. Juday in 1944. The papers published by this team in collaboration with each other, with other persons and singly are noteworthy contributions to the foundation of the present science of aquatic biology and fish management. Dr. Birge's papers, "The Thermocline and Its Biological Significance" (1904) and "The Respiration of an Inland Lake" (1907) are truly classical essays in the biological field and are a "must" to be read by every fishery worker.

Practically every factor affecting the ecology of lakes was investigated in an attempt to determine the how and why of their productivity. Temperature, light, dissolved gases, mineral and organic content, pH, and penetration of solar radiation into lake water were all investigated in a thorough and scholarly manner.

Although Dr. Birge held many positions of high responsibility and received many honors while he was alive, and many well earned tributes and memorials have been paid since his death, perhaps the most outstanding tribute that can be made is to remind ourselves that in our every day work we are applying one or more of the principles that Dr. Birge and his associates so painstakingly worked out and intelligently recorded.—*Edward Schneberger.*

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[1] Photograph by Harold N. Hone.

FISH HARVESTING ON TWO TVA MAINSTREAM RESERVOIRS[1]

LAWRENCE F. MILLER
Tennessee Valley Authority
Decatur, Alabama

ABSTRACT

From 1945 to 1950 a series of fish-tagging studies has been conducted on two TVA mainstream reservoirs to determine the extent to which the crop is being harvested. The fish taken in hoop nets and seines were tagged in the upper left jaw with a No. 3 Monel metal tag and released in the immediate vicinity of their original capture. Sportsmen cooperated in the studies from 1948 through 1950. TVA census takers, Sportsmen's Club members, and the anglers checked the catches and turned in the tags taken from the fish.

White crappie and white bass are the major sport fish in these two reservoirs. Poor harvesting of the sport fish crop is indicated by the fact that out of 6,028 fish tagged on Wheeler Reservoir from 1945 to 1950, only 89 tags have been returned (1.5 percent). On Guntersville Reservoir during 1948 to 1950, 5,506 fish have been tagged with a total of 53 tags returned (1.0 percent).

Mortality from tagging does not appear to be a factor in the low return of marked fish. In a separate mortality study, where 100 each of tagged and untagged white crappie were observed, 8 tagged and 15 untagged fish died.

Tagging studies on Guntersville Reservoir indicate a trend toward overpopulation of the white crappie. Most fish on TVA waters grow rapidly, but on Guntersville Reservoir 4-year-old crappie were only 8.6 inches long. Fifty percent of the crappie tagged were in the 7- to 8-inch group and 36 percent were in the 8- to 9-inch group.

INTRODUCTION

A fish marking and recovery program has been carried on in Wheeler and Guntersville reservoirs, two mainstream impoundments of the Tennessee Valley Authority in northern Alabama, from 1945 to 1950 to determine the extent of utilization of the fish populations. The results from the 1945 and 1946 operations were reported by Miller and Bryan (1947). The experiments from 1947 to August 1, 1950, are reported in the present paper. In Wheeler Reservoir the studies for the most part centered around the Decatur Harbor area, near Decatur, Alabama. In 1950 the Flint Creek and Elk River areas of the reservoir were also included. In these three areas fishing is much more intensive than in the reservoir as a whole. The studies on Guntersville were all made within 10 miles of the town of Guntersville, Alabama.

Tagging methods were similar to those used in the Norris Reservoir investigations (Eschmeyer, 1942) and in the earlier Wheeler investigations (Miller and Bryan, loc. cit.). The fish used for tagging were caught in hoop nets (99 percent) and seines (1 percent), and after measuring and marking were released in the same area where they were caught.

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[1] Published with permission of the Tennessee Valley Authority.

All fish were marked by placing a serially numbered, No. 3 Monel strap tag over the left maxillary and premaxillary. The date and place of capture, species, location of tagging, and total length in inches were recorded for each fish. Water levels and air and water temperatures were also noted on each day of the study.

The 1945-1946 experiments were confined to Wheeler Reservoir where TVA biologists tagged 898 white bass (*Lepibema chrysops*) with 1 recaptured in 1945; and 963 white crappie *(Pomoxis annularis)* and 37 black crappie (*Pomoxis nigromaculatus*) with 11 recaptured and 151 white bass with 3 recaptured in 1946. These results suggested that most white crappie and white bass were not being harvested. They were in agreement with findings for several species on Norris Reservoir, a TVA storage impoundment in east Tennessee (Miller and Bryan, loc. cit.).

METHOD OF TAG RECOVERY

Tags were recovered through the combined efforts of census clerks, extensive publicity, and active cooperation of local sportsmen's clubs. The program was publicized by personal contacts, periodic press and radio releases, posters, and talks before civic and sportsmen's clubs. In addition, TVA census takers were stationed in both areas at least 5 days each week during the spring fishing season. Besides checking the anglers' catch for tags, the census takers kept the anglers informed about the inquiry and urged them to report all tagged fish recaptured.

Beginning in 1948, sportsmen's clubs and other interested organizations in the area were encouraged to participate in tagging studies.[1] This cooperation helped to educate the sportsmen, and promoted a greater return of tags. However, despite the active cooperation of the clubs with its attendant publicity and increased interest, the percentage of recapture was not appreciably changed.

On Guntersville Reservoir sportsmen began to cooperate in 1948. Harvesting that year was 1.2 percent[2] as compared with 0.9 percent on Wheeler with no sportsmen participation. In 1949 and 1950, the harvesting percentage was 0.8 and 0.5, respectively (Table 1). On Wheeler Reservoir, participation of sportsmen began in 1949. The highest percentage of tags recaptured prior to that year was 1.3 in 1947, based on the number of fish tagged and recaptured in that year. With sportsmen participation, harvesting reached 1.5 percent in 1949 and 3.2 percent in 1950. The increase in 1950 was caused in part by a change in area where fish were tagged from the mainstream section of the reservoir (Decatur Harbor area) to a backwater section (Flint Creek area) in which the

---

[1] Sportsmen's groups which helped catch fish for tagging and gave prizes for returned tags were: Marshall County Conservation Club (Guntersville Reservoir, 1948, 1949, 1950); Morgan County Sportsmen and Conservation Association (Wheeler Reservoir, 1949, 1950); Limestone County Junior Chamber of Commerce (Wheeler Reservoir, 1949, 1950).

[2] For the purpose of the comparisons in this and the following paragraph, it is necessary to use percentages based on the number of fish tagged and recaptured in the same year. Figures so derived are in most cases different from those in Table 1, which are based on total numbers recaptured in all succeeding years from the number tagged in any given year.

TABLE 1.—*Total number of tags placed on fish of all species and tags returned in Guntersville Reservoir — 1948 to 1950.*

Year marked	Total tags	Year of recovery			Total recovered	Percentage recovered
		1948	1949	1950		
1948	2,000	24	1	....	25	1.2
1949	1,868	....	15	4	19	1.0
1950	1,638	....	....	9	9	0.5
Totals......	5,506	24	16	13	53	....
Total tags and percentage recovered after 1 year..........					48	91.0
Total tags and percentage recovered after 2 years..........					5	9.0

wind interfered less with fishing (Table 2). It is probable that some illegal fishermen and some who could not be reached by contact or publicity failed to return tags which were recovered by them. Loss from this source, however, is believed to be small.

MORTALITY CAUSED BY MARKING

The effect of tagging on survival of fish in TVA waters was first studied by Eschmeyer (1942). He tagged 102 largemouth bass *(Micropterus salmoides)* and 40 spotted bass (*Micropterus punctulatus*) in the Norris hatchery, and found that the tags did not cause fish mortality. For both species combined, the losses were 12 percent for tagged and 30 percent for untagged fish.

In order to secure additional information on the effect of tagging on fish survival, a study was initiated by the author in cooperation with Clark's Fishery, Decatur, Alabama, during the spring of 1950. For this

TABLE 2.—*Total number of tags placed on fish of all species, and tags returned in Wheeler Reservoir — 1945 to 1950.*

Year marked	Total tags	Year of recovery						Total recovered	Percentage recovered
		1945	1946	1947	1948	1949	1950		
1945	898	1	......	......	......	......	......	1	0.1
1946	1,174	......	14	1	......	......	......	15	1.3
1947	1,105	......	......	14	......	1	......	15	1.4
1948	1,000	......	......	......	9	3	......	12	1.2
1949	847	......	......	......	......	13	1	14	1.6
1950	1,004	......	......	......	......	......	32	32	3.2
Totals......	6,028	1	14	15	9	17	33	89	....
Total tags and percentage recovered after 1 year..............								83	93.0
Total tags and percentage recovered after 2 years..............								5	6.0
Total tags and percentage recovered after 3 years..............								1	1.0

study 200 white crappie were caught in hoop nets, 100 were tagged, and the lot was transported 5 miles in 25-gallon drums and placed in a 3-acre hatchery pond having a maximum depth of 7 feet. The amount of handling received by these fish was greater than that normally received by fish in routine tagging operations. The fish used for tagging were taken at random, were similar in length to the untagged fish, and ranged in length from 7 to 14 inches. The largest number of the tagged fish (21 percent) was in the 9-inch group, while the largest number of the untagged fish (23 percent) was in the 10-inch group.

Hatchery personnel observed the pond daily from April 20 to July 31, and noted 8 tagged and 15 untagged fish which died during this period. It is assumed, therefore, that in the period between April 20 - July 31 when most of the crappies were caught in the lake, tags did not cause mortality.

Marking and Recovery of Fish

Wheeler Reservoir.—Prior to 1950 fish tagging on Wheeler Reservoir was limited to the Decatur Harbor area directly opposite Decatur, Alabama (Figure 1). Because additional information was needed on other heavily-fished sections of the reservoir, and because spring weather conditions on the main reservoir area were adverse, the Elk River and Flint Creek areas were included in the harvesting studies in 1950.

Up to August 1, 1950, 6,028 fish were tagged on Wheeler Reservoir (Table 3). Of this number, 89 tags or 1.5 percent have been returned. All recaptures were made within the first three seasons after marking,

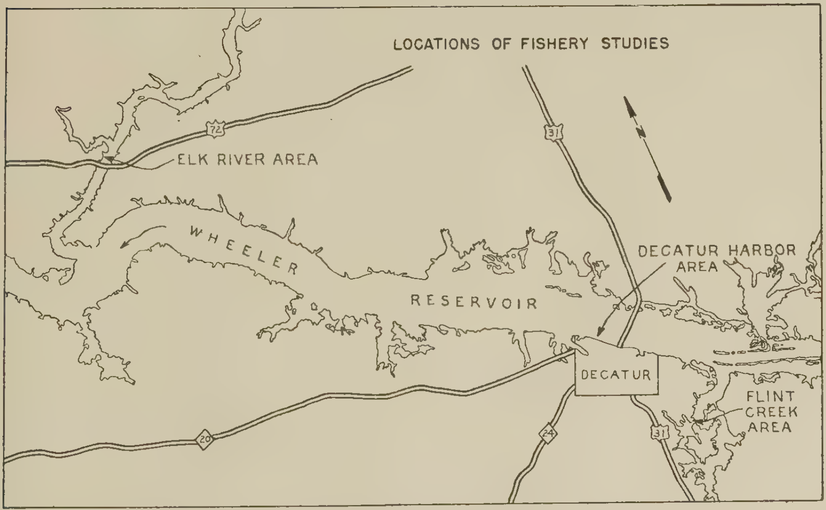


FIGURE 1.—Wheeler Reservoir of the Tennessee Valley Authority in the vicinity of Decatur, Alabama.

TABLE 3.—*Total fish marked and recovered (percentage recovered in parentheses) in Wheeler Reservoir—summarized by species for the years 1945 to 1950.*

Species	Year												Total tagged	Total recovered
	1945		1946		1947		1948		1949[1]		1950[1]			
	Total tagged	Total recovered	Total tagged	Total recovered	Total tagged	Total recovered	Total tagged	Total recovered	Total tagged	Total recovered	Total tagged	Total recovered		
White crappie	......	....	963	10 (1.0)	987	14 (1.4)	975	9 (0.9)	753	14 (1.8)	984	33 (3.3)	4,662	80 (1.7)
Black crappie	......	....	37	1 (2.7)	13	1 (7.7)	25	....	9	1 (0.1)	2	....	86	3 (3.5)
White bass	898	1 (0.1)	151	3 (2.0)	84	....	......	....	73	2 (2.7)	18	....	1,224	6 (0.5)
Yellow bass	......	....	23	....	21	....	......	....	3	....	......	....	47	....
Spotted bass[2]	......	....	......	....	......	....	......	....	9	....	......	....	9	....
Total	898	1 (0.1)	1,174	14 (1.2)	1,105	15 (1.4)	1,000	9 (0.9)	847	17 (2.0)	1,004	33 (3.3)	6,028	89 (1.5)

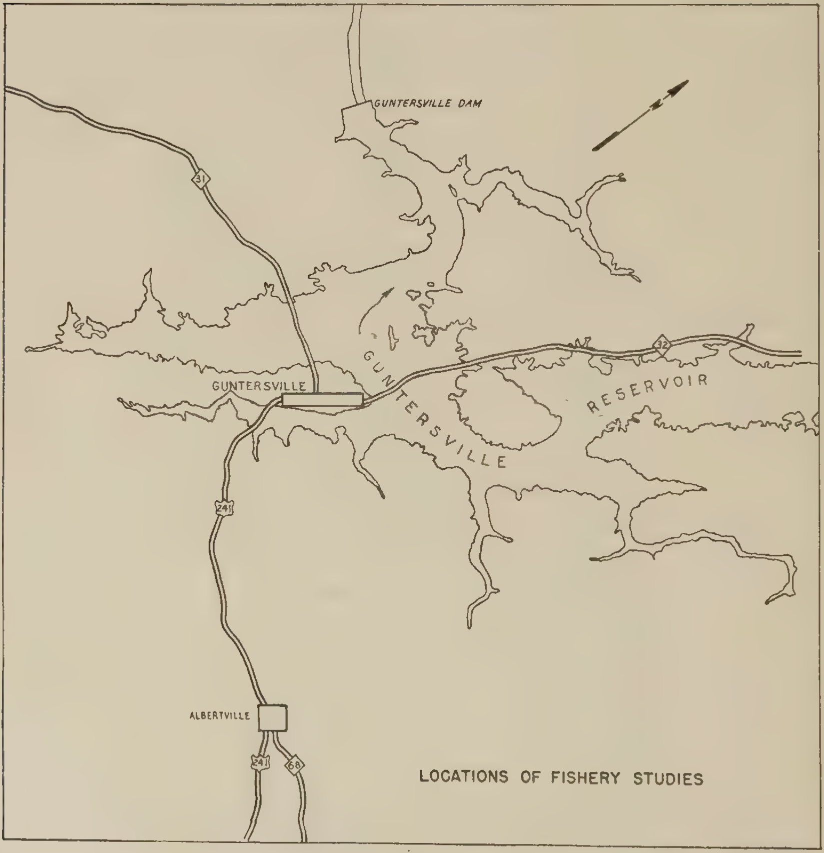
[1] Includes fish tagged on Elk River section 1949-1950 and on Flint Creek section 1950.
[2] Caught below Wheeler Dam and released on Elk River.

TABLE 4.—*Total fish marked and recovered (percentage recovered in parentheses) in Guntersville Reservoir—summarized by species for the years 1948 to 1950.*

Species	Year						Total tagged	Total recovered
	1948		1949		1950			
	Total tagged	Total recovered	Total tagged	Total recovered	Total tagged	Total recovered		
White crappie	1,920	22 (1.1)	1,816	12 (0.7)	1,600	7 (0.4)	5,336	41 (0.8)
Black crappie	73	1 (1.4)	25	....	6	....	104	1 (1.0)
Largemouth bass	2	1 (50.0)	2	....	....	....	4	1 (25.0)
Spotted bass	5	....	25	4 (16.0)	32	6 (3.1)	62	10 (16.1)
Totals	2,000	24 (1.2)	1,868	16 (0.9)	1,638	13 (0.8)	5,506	53 (1.0)

with 93 percent returned the first season, 6 percent the second season, and 1 percent the third season (Table 2). The percentages of tag returns for all species are much lower on the mainstream reservoirs than on the storage reservoirs where they have been as high as 17.4 percent on Norris and 26.3 percent on Hiwassee (Manges, 1950). In contrast to Norris Reservoir where rate of return from year to year has been variable, returns from Wheeler and Guntersville reservoirs have been consistent.

Size distribution of the tagged white and black crappie ranged from 5½ inches to almost 17 inches, with 75 percent of all fish falling between 6 and 11 inches, and 13 percent above 12 inches. Beginning in 1948 efforts were made to tag fish 7 inches or longer in length. Consequently, only a very small number of 6-inch crappies were tagged during 1948,


GUNTERSVILLE DAM
31
GUNTERSVILLE
GUNTERSVILLE RESERVOIR
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ALBERTVILLE
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68
LOCATIONS OF FISHERY STUDIES

Figure 2.—Guntersville Reservoir of the Tennessee Valley Authority in the vicinity of Guntersville, Alabama.

1949, and 1950. The marked white bass ranged in size from 6 inches to 17 inches with 70 percent in the 6- to 8-inch group. Yellow bass ranged in size from 5 to 12 inches with 71 percent of the fish in the 6- to 8-inch group.

Guntersville Reservoir.—Tagging studies were conducted on Guntersville Reservoir in 1948, 1949, and 1950 (Figure 2). Up to August 1, 1950, 5,506 fish were marked, and 53 or 1.0 percent were returned (Table 4). During this period, 5,336 white and 104 black crappie were marked. Of these, only 41 (0.8 percent) of the white-crappie and one (1.0 percent) of the black-crappie tags have been returned. Of 62 spotted bass tagged, 10 (16.1 percent) have been returned. Four largemouth bass were tagged and one tag has been returned. The harvesting of crappie on Guntersville is very similar to that on Wheeler and Fort Loudoun where the percentage of return is similar, and where returns are relatively consistent from year to year. On Guntersville Reservoir, 91 percent of the recoveries were made the first season after tagging, 9 percent were made the second season, and none the third. The second-season recaptures consisted of one white crappie in 1949 and three white crappie and one spotted bass in 1950 (Table 4).

Crappies tagged in Guntersville ranged in size from 6 to almost 15 inches total length. Fifty percent were 7 to 8 inches long, and 36 percent were 8 to 9 inches long. Only 13 percent were 9 inches or longer, as compared to 48 percent of the fish marked in Wheeler Reservoir. The 4 largemouth bass tagged in Guntersville Reservoir ranged in size from 9 through 20 inches. The spotted bass which were tagged ranged in size from 6 to 18 inches with 51 percent of all fish being in the 8- to 10-inch group.

Fish Movement

The movement of crappie, from the point of tagging to point of recapture, averaged 3.2 miles on Wheeler and 2.0 miles on Guntersville. White bass moved an average of 5.1 miles on Wheeler Reservoir. Here, as on storage waters (Manges, loc. cit.), the fish appear to move rather extensively.

Conclusion

The recapture of only 1.5 percent of the tagged fish in Wheeler Reservoir and 1.0 percent in Guntersville Reservoir indicates a poor rate of harvest. Since the areas studied were fished much more heavily than other backwater areas in the reservoirs, harvesting for the impoundments as a whole was probably much less than 1 percent. Crappie are hard to take after they leave the backwaters at spawning time. A return to the closed season would reduce the catch still further and therefore be undesirable.

A preliminary check of white crappie scales from Guntersville Reservoir reveals a relatively slow rate of growth with 4-year-old fish averaging only 8.6 inches in length. Since the population may become stunted if it continues to increase in numbers, it would be desirable to harvest a much larger percentage of the available fish than is now taken. Adequate utilization of this species would probably require commercial netting, but public acceptance of such a program is improbable. In any event an increase in creel limit or complete removal of limits would be desirable.

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A TEN-YEAR CREEL CENSUS ON LAKE PAWHUSKA, OKLAHOMA

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Abstract

Lake Pawhuska, an artificial lake of 95 surface acres, was first open for angling June 2, 1939. Continuous creel records were kept from the opening day until December 31, 1948. Numbers of fish removed as well as numbers of fishermen were recorded during the whole period. In addition, weights of fish were kept between January 1, 1943, and December 31, 1948.

During the period of approximately 10 years 23,442 fisherman-days resulted in the removal of 44,072 fish from the lake. The four dominant groups of fishes were crappie, bluegill, black bass, and miscellaneous sunfish. From January 1, 1943, to December 31, 1948, 11,964 fishermen harvested 12,021.8 pounds of fish. This is an annual average of 21.1 pounds of fish per surface acre during the 6-year period. In total pounds removed during this period, black bass, crappie, channel catfish, and bullhead ranked in the order noted.

Introduction

Good management of impounded waters depends upon thorough records of production. The present study of Lake Pawhuska, Oklahoma, analyzes the results of 10 years of continuous creel census extending from 1939 to 1949. The data are especially useful because they follow the production from the time the reservoir was filled through the initial advance of populations to a period of normal annual fluctuation. Lake Pawhuska is located in Osage County, 3½ miles from Pawhuska, a city of approximately 6,000 people. In July, 1939, the lake was half full of water. By June, 1941, the lake filled and the water ran 14 inches deep over the spillway. The lowest water level during the period of observation was 10 feet 6 inches below spillway level in 1947. Normally the water level has fluctuated approximately 6 feet each year. At spillway level the lake holds 2,850 acre-feet of water and covers an area of 95 acres. Approximately 5 acres have a depth of 5 feet or less and the maximum depth is 55 feet. The drainage area consists of 1,600 acres of tall-grass pasture land. Since siltation has been negligible, the lake is clear and supports an abundant growth of chara and smartweed along most of the shoreline.

The monthly mean air temperature for the 10-year period, 1939-1948, ranges from averages of 33.5° F. for January to 81.4° F. for July and August, with a low of 21.4° F. in January, 1940, and a high of 87.5° F. in August, 1943.

According to local observers (records are not available) the lake was stocked in 1947 with largemouth black bass *(Micropterus salmoides)*, spotted black bass *(Micropterus punctulatus)*, white crappie *(Pomoxis annularis)*, black crappie *(Pomoxis nigro-maculatus)*, bluegill *(Lepomis macrochirus)*, green sunfish *(Lepomis cyanellus)*, redear sunfish *(Lepomis microlophus)*, yellow perch *(Perca flavescens)*, and channel catfish *(Ictalurus lacustris)*. In addition to these species several others were apparently well established in 1948 according to an unpublished Oklahoma Game and Fish Department report which stated:

"At the present time bass (largemouth and spotted), crappie, bluegill and channel catfish seem to be the dominant sports species. Other species taken in smaller numbers by means of gill nets during 1946 and 1948 were the black bullhead *(Ameiurus melas)*, green sunfish *(Lepomis cyanellus)*, longear sunfish *(Lepomis megalotis)*, orange spotted sunfish *(Lepomis humilis)*, redear sunfish *(Lepomis microlophus)* and spotted sucker *(Minytrema melanops)*."

"A collection made during 1946 indicated that the white crappie was present in larger numbers than the black crappie, but in 1948 there was evidence that the black crappie was the dominant of the two species."

CREEL CENSUS METHODS

This paper reports the results of a continuous creel census from the day the lake was first opened to fishing, June 2, 1939, through December 31, 1948. Except for certain periods during the first few years when a closed spawning season was maintained, catch records were made each day. The census clerks were able to collect creel data on the total catch, since there is only one entrance to the lake, and the complete absence of cabins or camping facilities on the lake insured that each daily catch record represented only 1 day's fishing effort.

As all fishermen were required to check in and out through a weighing and counting station, the two operators identified, counted, and weighed each fisherman's take by species. In the event the string included several fish of one species, they were weighed in the aggregate and the total weight recorded with the number of individuals. From June 2, 1939, until January 1, 1943, only the numbers of each species and the numbers of fishermen were recorded. From January 1, 1943, until December 31, 1948, individual weights or aggregate weights for each species were recorded. Numbers and pounds of each species were kept separately for night fishing during the years 1943, 1944, 1946, 1947, and 1948. All figures include night fishing, except where otherwise stated.

TABLE 1.—*Numbers of fishermen using Lake Pawhuska each month and year over the 10-year period from 1939-1948. Percentage of total fishermen is in parentheses.*

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
1939[1]	....	....	....	....	....	1,448 (56.3)	477 (18.5)	305 (11.8)	155 (6.0)	99 (3.8)	32 (1.2)	57 (2.2)	2,573 (11.0)
1940[2]	 0	 0	140 (6.8)	115 (5.6)	148 (7.2)	449 (22.0)	432 (21.1)	443 (21.7)	160 (7.8)	116 (5.7)	35 (1.7)	6 (0.3)	2,044 (8.7)
1941[2]	16 (0.5)	23 (0.7)	73 (2.1)	86 (2.4)	140 (4.0)	1054 (30.0)	573 (16.3)	575 (16.3)	523 (14.8)	300 (8.5)	115 (3.3)	46 (1.3)	3,524 (15.0)
1942[3]	25 (0.7)	27 (0.8)	220 (6.6)	....	420 (12.6)	750 (22.5)	644 (19.3)	667 (20.0)	365 (10.9)	167 (5.0)	44 (1.3)	8 (0.2)	3,337 (14.2)
1943	10 (0.4)	29 (1.2)	93 (3.8)	682 (28.2)	411 (17.0)	294 (12.2)	275 (11.4)	265 (10.9)	184 (7.6)	123 (5.1)	47 (1.9)	6 (0.2)	2,419 (10.3)
1944	5 (0.3)	16 (0.9)	106 (6.2)	189 (11.0)	314 (18.3)	248 (14.5)	224 (13.1)	213 (12.4)	194 (11.3)	175 (10.2)	29 (1.7)	3 (0.2)	1,716 (7.3)
1945	7 (0.4)	11 (0.7)	157 (9.9)	169 (10.7)	210 (13.3)	325 (20.6)	329 (20.8)	144 (9.1)	131 (8.3)	61 (3.9)	24 (1.5)	11 (0.7)	1,579 (6.7)
1946	8 (0.6)	34 (2.4)	166 (11.8)	111 (7.9)	224 (15.9)	308 (21.9)	206 (14.7)	183 (13.0)	89 (6.3)	60 (4.3)	9 (0.6)	7 (0.5)	1,405 (6.0)
1947	5 (0.3)	2 (0.1)	41 (2.1)	323 (16.3)	236 (11.9)	305 (15.4)	280 (14.1)	169 (8.5)	242 (12.2)	289 (14.6)	68 (3.4)	25 (1.3)	1,985 (8.5)
1948	 0	10 (0.3)	77 (2.7)	448 (15.7)	766 (26.8)	472 (16.5)	366 (12.8)	306 (10.7)	208 (7.3)	158 (5.5)	40 (1.4)	9 (0.3)	2,860 (12.2)
Totals	76 (0.3)	152 (0.6)	1,073 (4.6)	2,123 (9.1)	2,869 (12.2)	5,653 (24.1)	3,806 (16.2)	3,270 (13.9)	2,251 (9.6)	1,548 (6.6)	443 (1.9)	178 (0.8)	23,442 (100.0)

[1] Lake open for fishing June 2, 1939.
[2] Lake closed from April 15 to May 30.
[3] Lake closed from April 1 to May 16.

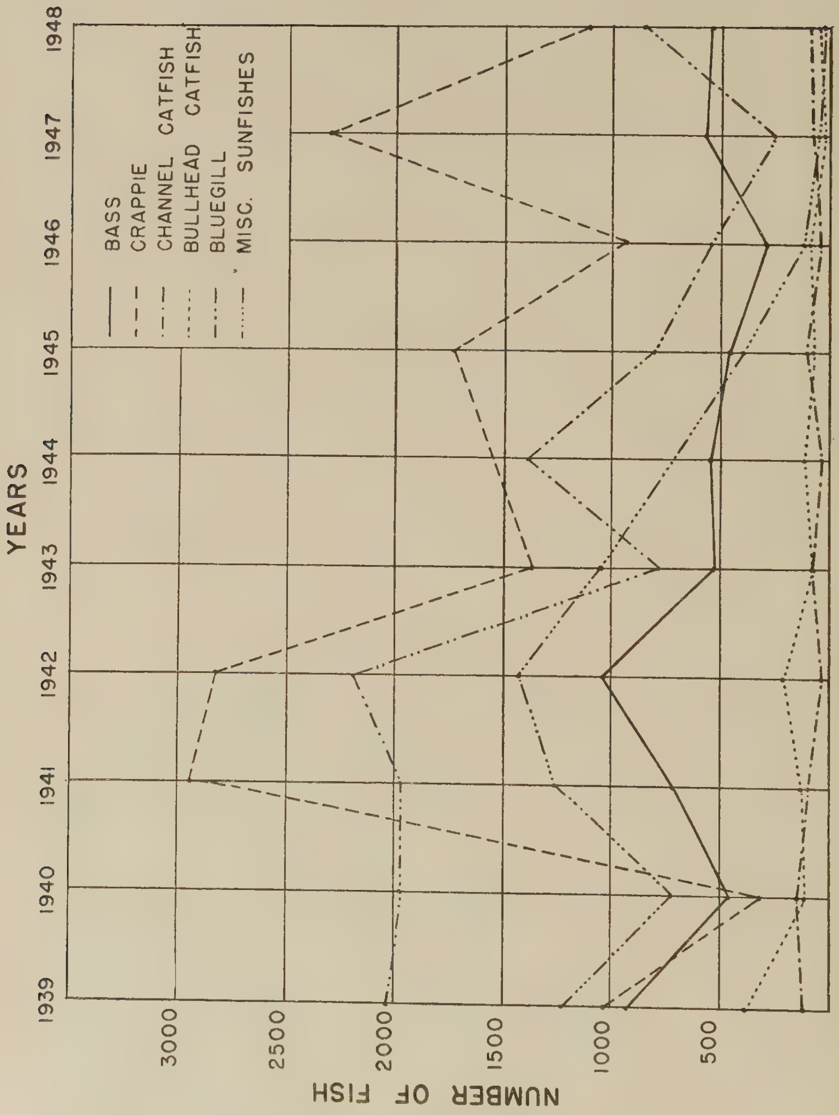

FIGURE 1.—Numbers of fish taken each year from Lake Pawhuska.

Largemouth black bass *(Micropterus salmoides)* and spotted black bass *(Micropterus punctulatus)* were included in one category designated as "bass." Two species of crappie *(Pomoxis nigro-maculatus* and *Pomoxis annularis)* were recorded together. Bluegill, yellow perch, and redear sunfish were separated and listed according to species. The category designated as unidentified sunfishes includes all other sunfish species, but primarily the green sunfish, longear sunfish, and the orange spotted sunfish made up this group. No game fishes were recorded which were below legal length (6 inches total length for crappie, 10 inches for bass and channel catfish).

DISTRIBUTION OF FISHING EFFORT

A total of 23,442 fishermen visited the lake during the 10-year period (Table 1). More fishermen used the lake during the month of June on the average than any other month (24.1 percent of total for 10 years). Apparently the primary reason for the increased activity during this month was the closed season during the early part of 1939, 1940, 1941, and 1942. For these first 4 years, the closed season was observed during all or part of the months of April and May (Table 1). Had it not been for the closed seasons the months of April, May, and June would probably have had nearly comparable numbers of fishermen. A regular decrease in total numbers of fishermen is noted (Table 1) from July through January. The 4 months of November, December, January, and February are represented by only 3.6 percent of the total number of fishermen for the 10-year period. In 1939, 56.3 percent of the total number of fishermen visited the lake the first month it was open for fishing.

The legal size and bag limits as well as size and species preference of individual fishermen resulted in some selection. For instance, more fish were caught by fishermen than were actually removed from the lake. It is known that fishermen at times caught many small crappie and bass, but they selected the larger ones for removal.

Most of the crappie and many of the bass were taken on live minnows. A smaller number of bass were caught on artificial flies and plugs. Worm fishermen took most of the bluegills. Fly fishermen are thought to have taken most of the green sunfish. Catfish were caught on a variety of baits including cut baits, worms, liver, and commercial baits.

TABLE 2.—*Estimated percent of anglers who fished for different species and baits most commonly used.*

Percentage of fishermen	Species sought	Baits used
35	Crappie	Minnows
25	Black bass	Minnows, plugs, and flies
10	Catfish	Catfish baits
10	Bluegill and other sunfishes	Worms and artificial flies
20	Anything	Miscellaneous

TABLE 3.—*Numbers of fish harvested from Lake Pawhuska from June 2, 1939 through December 31, 1948 (23,442 fishermen days).*

Species	Number	Percentage of total	Number of fish per fisherman
Crappie	16,269	36.91	0.69
Bluegill	12,035	27.31	0.51
Unidentified sunfishes	7,150	16.23	0.31
Bass	6,210	14.09	0.26
Bullheads	1,311	2.97	0.06
Channel catfish	883	2.00	0.04
Yellow perch	190	0.43	0.01
Redear sunfish	24	0.05	0.00
Totals	44,072	99.99	1.88

The majority of the fishermen using the lake were from the immediate vicinity, but a large number came from neighboring towns and areas. The estimated classification of fishermen by species preference and bait preference is shown in Table 2.

RATE OF EXPLOITATION

From June 2, 1939, through December 31, 1948, a total of 44,072 fish were removed from the lake (Table 3). This catch represents an average of 1.88 fish per fisherman-day for 10 years. From January 1, 1943, through December 31, 1948, 11,964 fishermen took 12,021.8 pounds of fish (Table 4). This catch is an average of slightly more than 1 pound per fisherman-day for this period. During the last 6 years, 21.1 pounds of all fishes per surface acre per year were harvested from Lake Pawhuska.

Crappie was the most abundant group in the creel. Following in order were: bluegill, unidentified sunfish, bass, bullhead, channel catfish, yellow perch, and redear sunfish (Table 3).

TABLE 4.—*Numbers and pounds of fishes harvested from Lake Pawhuska from January 1, 1943 through December 31, 1948 (11,964 fishermen-days).*[1]

Species	Number of fish	Number of pounds	Average weight in pounds	Percent of total number	Percent of total weight	Number per man	Pounds per man	Pounds per surface acre per year
Bass	2,974	3617.50	1.22	14.76	30.09	.25	.30	6.28
Crappie	9,086	3282.00	.36	45.09	27.30	.76	.27	5.76
Channel Catfish	472	2558.75	5.42	2.34	21.28	.04	.21	4.49
Bullhead	486	636.75	1.31	2.41	5.30	.04	.05	1.12
Bluegill	4,708	1240.75	.26	23.36	10.32	.39	.10	2.18
Unidentified sunfishes	2,426	686.00	.28	12.04	5.71	.20	.06	1.27
Totals	20,152	12,021.75	....	....	....	1.68	1.00	21.1

[1] No yellow perch or redear sunfish were recorded during these years.

Table 5.—*Numbers and weight (pounds) of all fishes harvested each year from Lake Pawhuska—1939-1948.*

Item	Year									
	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948
Number of fish	5855	2966	7243	7856	3938	4455	3617	2100	3326	2716
Percent by number	13.29	6.73	16.44	17.83	8.94	10.11	8.21	4.76	7.55	6.16
Number by pounds	....	....	....	....	2167.5	2097.5	2100.0	1357.3	2079.5	2220.0
Percent by weight (6 years)	....	....	....	....	18.03	17.45	17.47	11.29	17.30	18.47
Number of fishermen	2573	2044	3524	3337	2419	1716	1579	1405	1985	2860
Number of fish per fisherman	2.28	1.45	1.98	2.35	1.63	2.60	2.29	1.49	1.68	0.95
Number of pounds per fisherman	....	....	....	....	0.90	1.22	1.33	0.97	1.05	0.78

For the 6-year period ending on December 31, 1948, a larger weight of bass was taken than that for any other group (30.09 percent of total). Crappie and channel catfish followed closely with 27.30 percent and 21.28 percent of the total, respectively. Other less important groups by weight were bluegill 10.32 percent, unidentified sunfish 5.71 percent, and bullhead 5.30 percent of the total. Redear sunfish were not recorded separately during these years. Yellow perch did not occur in the creel during the last 6-year period.

ANNUAL CHANGES IN AVAILABILITY

Since the fish population of Lake Pawhuska has probably changed in abundance, growth rates of fish have varied, and the average ability of anglers during the 10 years is uncertain, it is difficult to use creel census as an indicator of total fish population in the various years. Larger numbers of available fish below legal length or below the sizes preferred by fishermen would not have been recorded in the creel. However, changes in harvest do suggest changes in availability of larger fishes. A few annual changes in availability are at least worthy of mention.

For the years studied, 47.5 percent by number of all fishes harvested were taken during 1939, 1941, and 1942 (Table 5). The largest numbers were taken during 1942 (17.83 percent), 1941 (16.44 percent), and 1939 (13.29 percent). The fishing season of 1939 consisted of only the last 8 months; therefore, the relative number taken in that year is probably nearly comparable to the numbers taken in 1941 and 1942.

The harvest in 1940 (Table 5) was exceptionally low in comparison to the other early years (1939 to 1944). The apparent explanation lies in the reduced fishing effort (number of fishermen) and a slight reduction in the degree of fishing success (Figure 2). Figure 1 shows fewer fish of several species taken in 1940.

The number of fish per fisherman-day and the number of pounds per fisherman-day has fluctuated from year to year in a somewhat cyclic pattern (Figure 2). The number of crappie harvested each year shows approximately the same pattern (Figure 1).

The number of pounds taken from the lake for the years 1943, 1944, 1945, 1947, and 1948 ranged from 2,097.5 to 2,220.0 (Table 5). Only 1946 fell below with 1,357.3 pounds (weights were recorded only between January 1, 1943, and December 31, 1948). Fishermen captured the highest average per man (1.33 pounds) in 1945, the lowest (0.78 pounds) in 1948 (Figure 2). During 1948, the last year studied, there was also an all-time low in numbers taken per man. The low crappie catch for that year accounted, in part at least, for the low harvest rate.

MONTHLY CHANGES IN AVAILABILITY

For the 10-year period, nearly twice as many fish were caught during the month of June as for any other month (Table 6). June is repre-

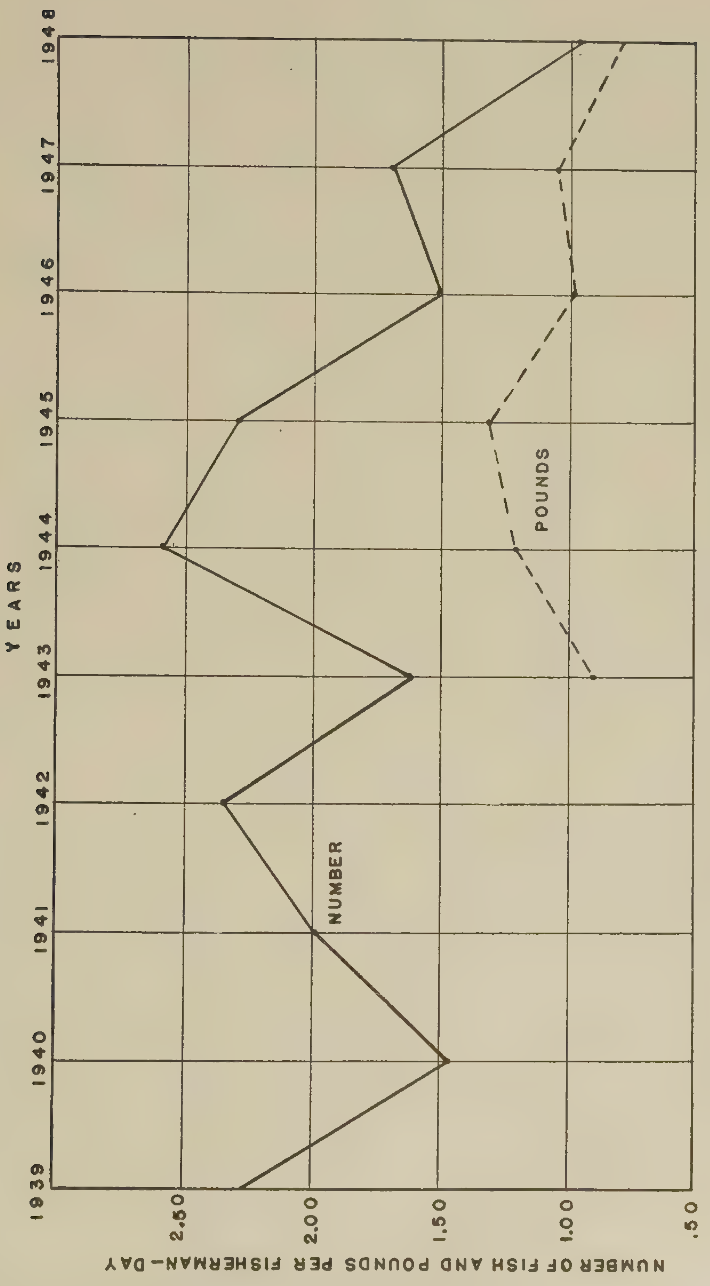

FIGURE 2.—Numbers and pounds of fish per fisherman-day taken from Lake Pawhuska annually each year—1939-1948.

TABLE 6.—*Total numbers of fish caught in 10 years of creel census from Lake Pawhuska.*

Item	Month											
Kind of fish	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Bass	2	17	433	586	827	1,267	905	824	766	494	64	25
Crappies	....	5	245	1,415	1,512	2,909	2,375	1,728	2,587	2,548	743	202
Channel catfish	....	1	2	19	50	289	217	195	79	27	4	0
Bullheads	....	....	45	99	239	569	125	95	67	44	6	22
Bluegill	....	5	58	501	1,502	5,462	1,911	1,222	702	537	135	....
Unidentified sunfishes	....	2	52	203	990	1,847	1,321	1,029	992	605	109	....
Yellow perch	....	....	....	2	17	103	15	12	25	15	1	....
Redear sunfish	....	....	....	4	9	10	1	....	....	....	....	....
Total fish	2	30	835	7,829	5,146	12,456	6,870	5,105	5,218	4,270	1,062	249
10-year catch percentage	0.00	0.07	1.89	6.42	11.68	28.26	15.59	11.58	11.84	9.69	2.40	0.56
Number of fish per fisherman	0.03	0.20	0.78	1.33	1.79	2.20	1.81	1.56	2.32	2.76	2.40	1.40

sented by 28.26 percent of the total, while July had the second highest catch record with 15.59 percent. The months of May, August, and September had comparable numbers representing slightly over 11 percent each. There was a general increase in numbers of all species taken in June. It must be emphasized again, however, that the closed seasons throughout all or parts of April and May for 1939, 1940, 1941, and 1942 probably accounted for the lower figures for the 2 previous months. Fishing effort for the month of June during the whole 10-year period is seen to be much greater than for any other month (Table 1). The closed season in previous months thus caused a sharp increase in the number of fishermen for June and thereby explains in part the greater take for that month. The average number of fish taken per fisherman increased steadily from January to June, but decreased again in July and August (Table 6). September, October, and November on the average had the greatest catch per unit of effort. Better fishermen may have been a factor in determining fishing success during the fall and early winter months.

It is of special interest that 64.51 percent of the fish caught in 1939, the first year, were taken during the opening month of June; furthermore, 30.28 percent of the total for that year were caught during the first 6 days of the season. In 1940, 45.85 percent of the total for the year were taken in the first 32 days following the closed season. In 1941, 24.59 percent of the year's total harvest was taken in the first 32 days following the closed season. In each of these cases the increase in numbers of fish taken corresponds to an increase in the number of fishermen (Table 1).

NIGHT FISHING

For the 5 years when night angling was observed 1,125 night fishermen took a total of 796 fish weighing 1,712.4 pounds (Table 8). By weight, 73.22 percent of the total for the period was channel catfish, 12.73 percent bullheads, 7.61 percent bass, 4.93 percent crappie, 1.12 percent unidentified sunfishes, and 0.39 percent bluegills. Night fishermen on the average took 1.52 pounds per fishing trip. This average is somewhat better than that for day fishermen. The fact that channel catfish and bullheads were predominant in night catches and the average size of the two species is larger than the average of all species, would probably explain a greater number of pounds per fisherman trip.

The few bass taken at night averaged slightly larger than those taken during the day. This difference could have been a result of selection of larger specimens by larger baits. The average sizes of all other species taken at night were similar to those from day catches.

HARVEST RATE OF EACH SPECIES

Bass.—From June 3, 1939, through December 31, 1948, a total of 6,210 largemouth black bass and spotted black bass were taken from the lake. This harvest was an average of approximately 621 fish per year. The largest number of these species taken for any one year was 1,065 individuals for 1942 (season closed 1½ months) (Figure 1). The first year (1939) was second highest in numbers, with 946 fish taken, even though the lake was not open for fishing during the first 5 months of that year. Actually more bass were taken per month during the first year of fishing than in any other year studied. For the whole 10-year period the numbers taken each year ranged from 291 to 1,065 bass. The year with the lowest rate of harvest was 1946. More than twice as many bass (564 fish) were taken in the opening month of June, 1939, as were taken in any other month of the 10-year period. On the average May and June were the best months for this species.

During the last 6 years, 2,974 bass were recorded weighing 3,617.5 pounds, an average of 6.28 pounds per surface acre per year. The average weight of the fish was 1.22 pounds. In this period the greatest poundage was taken in 1948; 5 of the 6 years had almost equal production, but 1946 was exceptionally low. This variation in harvest rate can be partially explained by changes in the fishing intensity (Table 1). A total of 2,860 fishermen were recorded for 1948 while only 1,405 were checked in 1946. The fishing effort for the other 4 years ranged between these two extremes.

Crappie.—A total of 16,269 crappie (36.91 percent of all fish) were taken from Lake Pawhuska in the 10-year period. Each fisherman on the average took 0.69 crappie per day of fishing. The total number of crappie harvested each year exceeded the catch of any other group

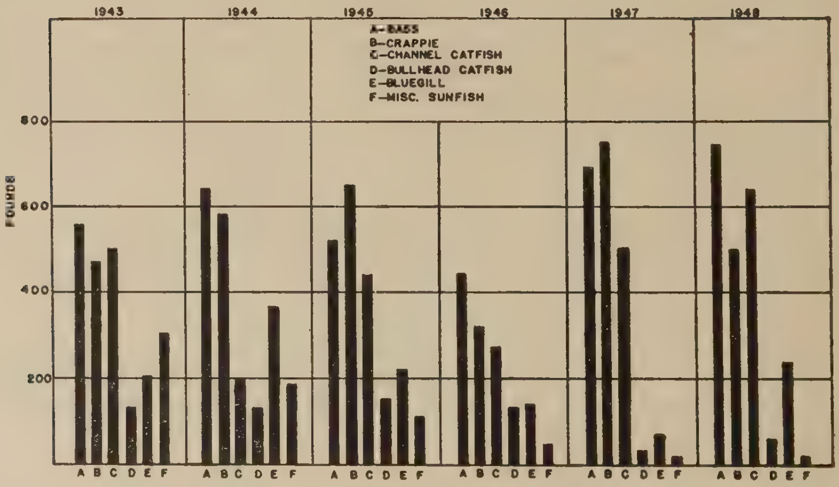

FIGURE 3.—Weight of each species of fish taken from Lake Pawhuska during the last 6 years studied.

except for the two initial years of 1939 and 1940 (Figure 1). The greatest production was in the third and fourth years (1941 and 1942) of the period. Thereafter the numbers fluctuated in alternate years or every 2 years, but at a much lower level (Figure 1).

January, February, March, November, and December are the months of lowest yield (4.9 percent of total for 10 years) (Table 6) but on an average only 8.2 percent of the total effort (fishermen days) was exerted during these months (Table 1).

During the last 6 years 3,282.0 pounds of crappie were removed from the lake. The yield per surface acre annually thus was 5.76 pounds. No other group exceeded this poundage except bass (Table 4). The years 1947 and 1945 were highest with 765 and 648.75 pounds, respectively. Weights were not recorded for the first 4 years, but on the basis of relative numbers taken during this period 1941 and 1942 were probably the two peak years. The average size of each crappie taken from 1943 to 1949 was 0.36 pound. The year 1947 had the lowest annual average size of 0.33 pound while 1948 had the highest annual average of 0.44 pound.

Channel Catfish.—In 10 years only 883 (2.0 percent of total) channel catfish were taken from Lake Pawhuska (Table 3). The numbers taken per year were highest in 1940 with 145 fish and lowest in 1942 with 40 fish (Figure 1). Seasonal distribution of harvest follows essentially the same pattern as that for crappie and bass with fewer channel catfish appearing in the creel during the colder months (Table 6). Individual channel catfish as large as 14 pounds 8 ounces were recorded as early as 1943. Assuming fingerlings were planted in the lake no earlier than 1937 this size would represent a growth of slightly better than 2 pounds per year. This assumption is strengthened by the observation of two individuals, collected in 1948, which averaged 11.5 pounds and were 6 years old (Ward and Thompson, 1948). The average size of channel catfish taken during the last 6-year period was 5.42 pounds. This large size of individuals caused the species to rank third in total weight with 21.28 percent of the total harvest. The average annual harvest per surface acre was 4.49 pounds (Table 4).

Bullheads.—The creel count showed a total catch of 1,311 bullheads or 2.97 percent of all fish taken during the 10-year period. Bullheads caught during the first 7 months after the opening day of fishing made up 29.37 percent of the total bullhead catch for 10 years. After the first year the annual catch was less than 200 individuals, except in 1942 when 216 fish were taken. The catch was small in 1947 (13 fish) and 1948 (28 fish) suggesting a trend toward smaller numbers as the lake became older. Correlated with the sudden drop in numbers is the increase in average size after 1943. The average weight increased from approximately 1 pound in 1943 to 2¼ pounds in 1948. These changes seem to indicate that the bullhead population is no longer able to replenish itself and only the larger and older individuals are left for the

TABLE 7.—*Weight (pounds) of fish taken each month from Pawhuska Lake during the 6 years from January 1, 1943 to December 31, 1948.*

Item	Month												
Kind of fish	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Bass	....	22.0	291.5	618.3	634.5	437.3	417.0	419.3	403.8	336.8	36.3	1.0	3617.8
Crappie	....	0.5	84.3	512.5	372.0	517.0	379.3	202.0	437.8	595.0	160.8	21.0	3282.2
Channel catfish	....	2.0	6.0	104.0	243.3	576.3	563.5	704.3	299.3	57.8	3.5	....	2559.0
Bullhead	....	....	47.5	96.5	222.3	128.0	44.5	58.0	22.0	18.0	....	....	636.8
Bluegill	....	1.5	3.8	139.0	257.0	411.8	213.8	114.0	59.8	25.8	14.5	....	1241.0
Unidentified sunfishes	....	1.0	9.0	54.0	194.3	98.0	148.5	46.3	88.5	33.0	13.5	....	686.1
Total	....	27.0	442.1	1524.3	1923.4	2167.4	1766.6	1543.9	1311.2	1066.4	228.6	22.0	12022.5

TABLE 8.—*Harvest of fish from Lake Pawhuska by night fishing expressed as numbers and pounds for the years 1943, 1944, 1946, 1947, and 1948.*

Item	Year										Total number	Total weight	Average weight (pounds)	Percent by number	Percent by weight
	1943		1944		1946		1947		1948						
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds					
Bass	21	25.8	16	31.5	23	40.0	3	8.0	18	25.0	81	130.3	1.61	10.17	7.61
Crappie	22	9.0	34	15.5	16	6.0	161	43.0	25	11.0	258	84.5	0.50	32.41	4.93
Channel catfish	49	288.0	21	106.8	39	223.0	64	385.0	44	251.0	217	1253.8	5.78	27.26	73.22
Bullheads	63	66.0	32	36.0	37	69.0	8	18.0	13	29.0	153	218.0	1.42	19.22	12.73
Bluegill	4	1.3	16	5.3	....	....	....	....	....	....	20	6.6	0.33	2.51	0.39
Unidentified Sunfishes.	23	7.0	44	12.2	....	....	....	....	....	....	67	19.2	0.29	8.42	1.12
Total	182	397.1	163	207.3	115	338.0	236	454.0	100	316.0	796	1712.4	....	....	....
Number of fishermen	308	....	144	....	170	....	235	....	268	....	1125	....	....	....	....
Number and pounds per fisherman	0.59	1.29	1.13	1.44	0.68	1.99	1.00	1.93	0.37	1.18	....	....	....	....	....

creel. From 1943 to 1949 the bullhead catch represented only 5.3 percent of the total weight of all fishes.

Bluegill.—In 10 years 12,035 bluegill or 27.31 percent of the total of all fish caught were taken from the lake. More bluegill were taken in 1939, 1941, and 1942 than during the other years studied. The numbers decreased considerably in 1943, but increased again in 1944. After 1944 there was a gradual decrease through 1947, when only 263 bluegill were taken. The last year, 1948, showed a gain to 851 fish. The bluegill taken during the first 4 years made up 60.9 percent of the total number for 10 years. In the last 6 years an average of 206.8 pounds per year of bluegill were harvested. This production represented 10.32 percent of the total weight of all fishes and an average of 2.18 pounds per surface acre per year. The average individual weight of all bluegill from 1943 through 1948 was 0.26 pound and the average weights for individual years were all near this figure. The highest annual production was 364.25 pounds in 1944 and the lowest take was 70 pounds in 1947.

Yellow Perch.—The yellow perch was introduced into Lake Pawhuska before 1939, but only 190 individuals ever reached the creel. Ninety-eight of these were taken in 1939 and the remaining 92 were taken in 1940, 1941, and 1942. Thereafter, no yellow perch were recorded. Stragglers are known to have been caught in later years, but were released because they were small.

Redear Sunfish.—Only 24 redear sunfish were taken from the lake in 10 years. This species was not represented in the creel after 1942.

Miscellaneous Sunfish.—In the 10-year period, 7,150 unidentified sunfishes were recorded. As has been mentioned previously, this group is made up of the orange-spotted sunfish, the longear sunfish, and green sunfish, with green sunfish believed to predominate. The peak in annual harvest occurred in 1942 when 1,432 fish were taken. Since then the catch has declined every year to a low of 24 in 1948. In the last 6 years, 686.0 pounds of this group, or 5.71 percent of the total weight of all fish were taken.

Discussion

The analysis of these data has been difficult, even though they represent continuous daily creel records of approximately 10 years' duration. A few important conclusions can, however, be drawn. As would be expected, more fish were taken in the early years of impoundment than in later years. In general, the number of fish taken was highest in 1942, but fell sharply after 1943. This drop indicates a decrease in the availability of certain larger sizes of fish, but not necessarily a decrease in the total population for the lake. Actually, fewer available fish of "keeper size" in later years may be a result of over-population, rather than under-population. Over-population has been observed repeatedly to result in growth rates so retarded that several of the youngest and most dominant year classes are eliminated from the creel because of insufficient size.

The high mortality rate and short life span of many southern species accentuate this tendency. If this phenomenon is applicable to Lake Pawhuska, as would seem highly probable, the rate of harvest has been lower than the annual increments.

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SAMPLING FISH POPULATIONS IN THE COOSA RIVER, ALABAMA[1]

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Abstract

Fish populations were sampled in two quarter-mile sections of the Coosa River near Childersburg, Alabama, during July and August, 1949. Sampling was done with hoop nets, wire baskets, and rotenone. In addition, the catch of a permanent fish trap was observed. The selectivity and limitations of each of these sampling methods are discussed. Since the methods used were to an appreciable extent complementary, it was possible to obtain significant information on nearly all important species. The most important species (by weight) taken were channel catfish, freshwater drum, smallmouth buffalo, flathead catfish, blue catfish, redhorse, and gizzard shad. None of the methods used was adequate for the sampling of game and pan species. The most important of these encountered were, however, white crappie, spotted black bass, and bluegill sunfish. Each of the methods failed completely to reveal the presence of one or more important species of fish. Since all sampling methods were selective, it was impossible to arrive at estimates of the relative or absolute abundance of the various species of fish. However, figures are given on the relative and absolute availability of the different species to the various sampling methods. The success of mark-and-recapture attempts to obtain estimates of relative abundance which were independent of the species selectivity of the gear was limited by the very small number of recaptures.

Introduction

The practical difficulties encountered in the investigation of stream fish populations severely limit the possibilities of quantitative study. These difficulties arise largely from the mobility of the populations, the movement of the water, and the extreme variability of many environmental factors.

Most methods of sampling fish populations provide data in the form of catch per unit of sampling effort. However, since any method of sampling is to some extent selective, quantitative estimates of real abundance cannot be obtained from these data alone. Such estimates can be made only when extensive mark-and-recapture studies are successful in determining the extent and nature of population movement, and the rate of recapture. Estimates may be made, nevertheless, of the relative and absolute availability of various segments of the population to standard gear operated under standard conditions. A generalized picture of the population as a whole may be gained when different sampling methods are applied to a population and their results compared and considered collectively. Such a comparison is made in the present study of sampling with hoop nets, wire baskets, and rotenone in two areas of the Coosa River. Permanent fish traps at one of the areas also provided a sample.

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[1] This investigation was conducted for the Water Improvement Advisory Commission for the State of Alabama with the cooperation of the Alabama Department of Conservation, Alabama Department of Public Health, and Alabama Polytechnic Institute.

SITES OF OPERATION

Two sections of the Coosa River, each about one-quarter mile long, were worked intensively. One section was 17 miles upstream from Childersburg, Alabama, at Willingham's Fish Trap, and the other 4.5 miles downstream from Childersburg on the farm of Mr. T. G. Wood. At Willingham's Fish Trap the river is 500 to 900 feet wide, and passes over a series of rock ledges. The average depth of the water is 5 feet or less, but there are scattered holes 10 feet in depth. The bottom consists of coarse gravel and boulders scattered among the bedrock ledges. Rare patches of muddy or sandy bottom may be found near the shore or in the lee of rocky islands. The steep gradient of the river bed causes the water in this section of the river to flow rapidly (usually more than 3 feet per second) and to change its velocity considerably with relatively slight change in river level.

At Wood's Farm the river makes a sharp bend and narrows to a width of 400 feet. The river banks below the water surface are composed of mud and organic debris and drop precipitously to depths (at low water) of 15 to 20 feet on the inside of the bend and 20 to 30 feet on the outer side. The river bed is covered with boulders and coarse gravel and slopes gently toward the outside of the bend where it becomes very uneven. Abrupt drops of as much as 20 feet indicate the presence of submerged rock ledges and isolated soundings as deep as 42 feet were made. Up and downstream from the bend the deepest part of the channel shifts toward midstream and does not exceed 35 feet in depth. The average rate of flow is 1 to 2 feet per second in midstream and somewhat slower near shore.

HOOP NET AND WIRE BASKET SAMPLING

Hoop nets were used from July 4 to September 1, 1949. Each net had six circular hoops grading in 3-inch steps from 4½ feet to 3¼ feet in diameter. The first half of each net, made of 1½-inch bar mesh, was 32 meshes long and 96 meshes in circumference. The nets were furnished with two funnels. The funnel in the first half, hung from the first hoop, was 16 meshes long and was finished with four strings in an opening about 1 foot square. The second half of each net, made of 1-inch bar mesh, was 84 meshes long and 96 meshes in circumference. The funnel in the second half, hung from the third hoop, was 21 meshes long and fingered. The nets were made of Number 15 medium twine treated with copper naphthanate. Nets were set with a tail anchor of sufficient weight to hold them against the current and with enough rope to allow the net to be raised into a boat. In cases where the current was

TABLE 1.—*Number of lifts and average depths of operation of hoop nets and wire baskets at two sites on the Coosa River.*

Item	Location			
	Wood's Farm		Willingham's	
	Hoop nets	Wire baskets	Hoop nets	Wire baskets
Number of lifts	164	61	157	71
Average depth (feet)	19.3	10.3	7.6	6.6

insufficient to hold the net extended, a head anchor was also used. When the nets were set close to shore, light cords were tied from head and tail anchors to the bank. In midstream, floats were tied to the head lines.

Wire baskets were used from July 16 to September 1, 1949. Each basket consisted of a cylinder of 1-inch mesh reinforcing wire, 4 feet long and 1½ feet in diameter. Two funnels in one end were made of three-quarter-inch mesh hardware cloth and were spaced 14 inches apart. The other end of the cylinder was closed with a cone made of the same material as the funnels. The opening in the first funnel was about 6 inches in diameter and that in the second about 4 inches. The latter opening was fitted with split oak strips which extended 4 to 6 inches straight back into the basket. Initially the nets and baskets were unbaited, but after July 18 most of them were kept baited with cottonseed cake. Catches were so variable that it could not be proved that baiting increased them significantly. The average depths at which the gear was fished and the number of lifts made at each site are shown in Table 1.

All fish taken in nets and baskets were weighed and measured to the nearest millimeter of total length. Weights were taken in grams or in pounds and ounces depending upon the size of fish and the equipment available. In a few instances it was necessary to estimate weights. Nearly all specimens of the common species encountered were returned to the river after having one of the ventral fins clipped off. At the Willingham site the left ventral fin was removed, and at the Wood Farm site the right ventral was clipped. Catch per lift of each unit of gear was selected as a measure of fishing success since periods of fishing which exceeded 1 day did not increase the catch significantly.

Hoop nets at Wood's Farm took, in order of their importance by weight, smallmouth buffalo, blue catfish, lake sturgeon, freshwater drum, channel catfish, and white crappie (Table 2). Game and pan fish (other than white crappie) made up less than 1 percent of the catch. Hoop nets at the Willingham site during the same period of time caught, in order of their importance by weight, flathead catfish, channel catfish, freshwater drum, smallmouth buffalo, redhorse, blue catfish, and gizzard shad. Game and pan fish made up only 1.6 percent of the weight of the catch. At Wood's Farm wire baskets caught relatively few fish (approximately

TABLE 2.—*Average catch per lift of hoop nets and wire baskets at the Wood's Farm and Willingham's Trap on the Coosa River — expressed as numbers and weight in ounces. Percentage of total is shown in parentheses.*

Species	Hoop nets				Wire baskets			
	Wood's Farm		Willingham's		Wood's Farm		Willingham's	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Lake Sturgeon *Acipenser fulvescens*	0.02 (0.6)	2.77 (6.1)	....	....	....	....	....	....
Longnose Gar *Lepisosteus osseus*	0.05 (1.7)	1.06 (2.3)	0.01 (0.4)	0.24 (0.8)	....	....	....	....
Spotted Gar *Lepisosteus productus*	0.01 (0.2)	0.03 (<0.1)	....	....	....	....	....	....
Gizzard Shad *Dorosoma cepedianum*	....	....	0.03 (0.8)	0.37 (1.3)	....	....	....	....
Smallmouth Buffalo *Ictiobus bubalus*	0.42 (14.9)	24.22 (53.1)	0.06 (1.9)	2.28 (7.8)	....	....	....	....
Redhorse *Moxostoma poecilurum*	0.01 (0.4)	0.16 (0.4)	0.20 (6.6)	1.74 (6.0)	0.05 (4.8)	0.28 (6.3)	0.32 (6.6)	2.15 (7.6)
Channel Catfish *Ictalurus lacustris punctatus*	0.67 (23.8)	2.70 (5.9)	1.43 (48.1)	8.32 (28.5)	0.54 (53.3)	2.36 (52.2)	4.31 (87.4)	21.49 (76.1)
Blue Catfish *Ictalurus furcatus*	0.55 (19.4)	7.51 (16.5)	0.08 (2.6)	1.30 (4.5)	0.02 (1.6)	0.03 (0.6)	0.04 (0.9)	0.77 (2.7)
Flathead Catfish *Pilodictis olivaris*	0.17 (6.1)	2.89 (6.3)	0.39 (13.1)	10.40 (35.7)	0.07 (6.5)	1.08 (23.9)	0.10 (2.0)	3.14 (11.1)
Spotted Black Bass *Micropterus punctulatus henshalli*	....	....	0.02 (0.6)	0.07 (0.2)	0.02 (1.6)	0.06 (1.3)	....	....
Green Sunfish *Lepomis cyanellus*	0.01 (0.2)	0.02 (<0.1)	0.01 (0.4)	0.02 (0.1)	0.02 (1.6)	0.12 (2.6)	....	....
Longear Sunfish *Lepomis m. megalotis*	....	....	0.01 (0.2)	0.05 (0.2)	0.15 (14.6)	0.19 (4.2)	0.01 (0.3)	0.01 (0.1)
Bluegill Sunfish *Lepomis m. macrochirus*	0.18 (6.5)	0.25 (0.5)	....	....	0.12 (11.3)	0.29 (6.4)	0.03 (0.6)	0.11 (0.4)
Warmouth *Chaenobryttus coronarius*	0.01 (0.2)	<0.01 (<0.1)	....	....	0.02 (1.6)	0.04 (0.9)	....	....
White Crappie *Pomoxis annularis*	0.33 (11.7)	1.29 (2.9)	0.03 (0.8)	0.15 (0.5)	0.02 (1.6)	0.02 (0.4)	....	....
Black Crappie *Pomoxis nigro-maculatus*	0.01 (0.2)	0.02 (<0.1)	0.01 (0.2)	0.06 (0.2)	....	....	....	....
White Bass *Lepibema chrysops*	....	....	0.03 (0.8)	0.19 (0.6)	....	....	0.06 (1.1)	0.15 (0.5)
Freshwater Drum *Aplodinotus grunniens*	0.40 (14.0)	2.72 (6.0)	0.69 (23.2)	4.01 (13.7)	0.02 (1.6)	0.05 (1.2)	0.06 (1.1)	0.40 (1.4)
Total catch per lift	2.84	45.64	3.00	29.20	1.05	4.52	4.93	28.22

one per lift). In order of their importance by weight these were channel catfish, flathead catfish, bluegill sunfish, redhorse, and longear sunfish. Other game and pan species amounted to slightly more than 1.3 percent of the weight of the average catch per lift. Wire baskets were far more effective at the Willingham site (approximately five fish per lift) where their catch was, in order of their importance by weight, channel catfish, flathead catfish, redhorse, blue catfish, and freshwater drum. Here, game and pan fish made up less than 0.6 percent of the weight of the average catch. According to experienced fishermen, these catches are comparable to what is usually caught by similar methods at this time of year.

Smallmouth buffalo and blue catfish made up nearly 70 percent of the weight of the net catch in the deeper water at Wood's while flathead catfish, channel catfish, and freshwater drum made up nearly 78 percent of the weight of the net catch at Willingham's. The only game and pan fish taken in any numbers in nets was the white crappie which made up nearly 3 percent of the weight of the catch of nets in deep water. Channel catfish and flathead catfish made up over 76 percent of the weight of the wire basket catch in deep water and these same species accounted for over 87 percent of the weight of the shallow-water basket catch. Sport fish were practically absent from the basket catches at Willingham's, but in deep water at Wood's, wire baskets did catch some bluegill sunfish (6.4 percent by weight).

Hoop nets and wire baskets did not catch all species with equal ease and their efficiency for catching any species varied according to the location and manner in which the gear was set. For example, wire baskets and hoop nets were about equally effective in taking channel catfish at the Wood site (0.54 and 0.67 fish per lift respectively), while at the Willingham site, wire baskets were about three times as effective as hoop nets for the same species (4.31 and 1.43 fish per lift). Although such variations prevent the making of accurate estimates of abundance, the data in Table 2 represent the relative and absolute availability of the various species at each site to each type of gear. Repetition of this study with identical gear in similar locations, therefore, should reveal any major population changes.

RECAPTURE OF MARKED FISH

In the present study it was hoped that estimates of abundance could be made for all the common species by the recapture of marked fish. These estimates could not cover any known area, but instead would be estimates of the populations within the fishing range of each group of nets and traps. Such estimates would not be entirely without meaning, however, for they could be used for comparison with subsequent identical experiments to detect any major quantitative changes in the populations. In addition, these estimates of absolute abundance would yield an estimate of relative abundance for each species which would be inde-

TABLE 3.—*Population estimates of channel catfish and flathead catfish at Wood's Farm and Willingham's Trap derived from marking and recovery of fish.*

Item	Species	
	Channel catfish	Flathead catfish
Wood's Farm		
Number fish marked	108	17
Number recaptures	12	6
Estimated population	565	35
Confidence limits (95 percent)	323—1093	16—95
Willingham Trap		
Number fish marked	453	27
Number recaptures	40	21
Estimated population	2,962	50
Confidence limits (95 percent)	2174—4143	33—80

pendent of catch per unit of effort and thus unaffected by the selectivity of the gear.

Very few of the fish caught and marked were recaptured. The channel and the flathead catfish were the only species for which more than four recaptures were recorded. None of the fish marked at Wood's were recaptured at Willingham's or vice versa. Only two marked individuals, both channel catfish, were taken in the rotenone samples and these were found within a half-mile of the point of original capture.

Population estimates (Table 3) were made for the channel catfish and flathead catfish by use of the Schnabel (1938) method. Catches of channel catfish by nets and baskets were combined because a comparison of the length frequencies of net and basket catches indicated that the two types of gear were apparently sampling the same range of sizes (Figure 1). Catches of flathead catfish from nets and baskets were also combined. In making these estimates, recruitment of unmarked fish into the catchable size range could not be taken into account. Recruitment of young fish probably was a factor in raising the estimates of channel catfish because an increasing number of young (presumably yearling) in the catch was noted late in the season.

Although these estimates are subject to considerable error, flathead catfish appear to be much less abundant than the channel catfish at both

TABLE 4.—*Estimated ratios of channel catfish to flathead catfish at the two sites of operation based upon catch per unit of effort by nets and baskets and upon recaptures of marked fish.*

Location	Catch per unit of effort		Recapture of marked fish
	Nets	Baskets	
Wood's Farm	4.0:1	7.7:1	16.3:1
Willingham's Trap	3.7:1	43.1:1	59.2:1

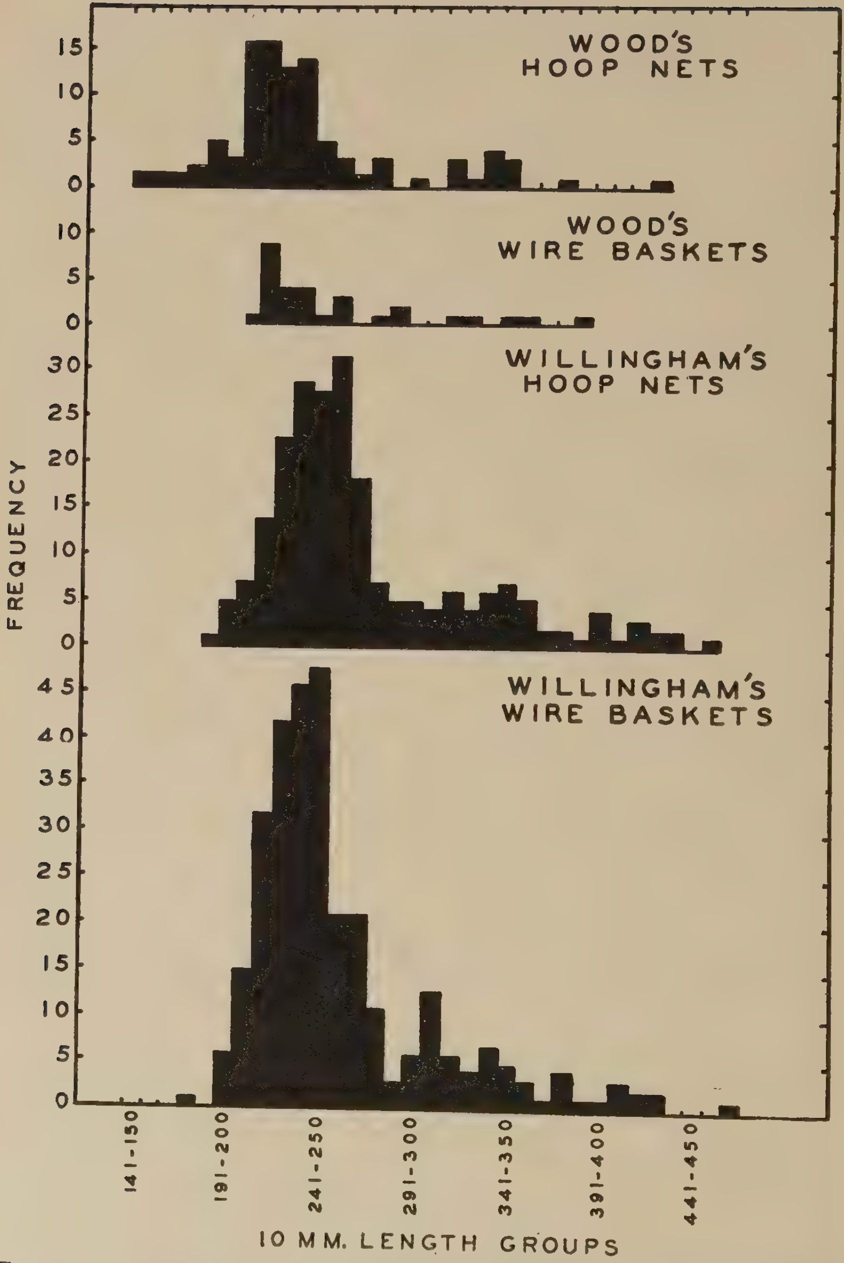

FIGURE 1.—Length frequencies of channel catfish caught in hoop nets and wire baskets at the Wood's Farm and Willingham's Trap.

sites of operation. Ratios of channel catfish to flathead catfish derived from these estimates are much different than those calculated from the catch per unit of effort of the nets (Table 4). The ratios of channel catfish to flathead catfish in the wire basket catches are almost certainly biased in favor of the channel catfish by the narrower limit on the size of fish that can be caught with this gear and the smaller average size of channel catfish. It would appear, therefore, that either the flathead catfish is much more vulnerable to netting or ranges less widely than does the channel catfish. If the channel catfish ranges more widely, the fishing efforts covered a larger area and a relatively larger population as far as this species was concerned, and a much more limited area as far as the flathead catfish was concerned. Thus, the two species might be more nearly equal in their real abundance than the estimates indicate. Because the areas covered by the gear were indefinite no comparison can be made of the populations at the two sites of operation.

ROTENONE SAMPLING

Two methods were used to distribute rotenone. In deep water, a curtain of poison was laid from surface to bottom around the area to be poisoned. In shallow water, a narrow channel between an island and the river bank was sought and poisoned by laying a straight curtain of rotenone across the upper end of the channel.

The rotenone used in the present work was in the form of a 5-percent emulsifiable solution. The emulsifiable solution seems to be much more effective and is more rapid in its action than the 5-percent powdered form. Rapidity of action is very important when poison is used in flowing streams. The 5-percent solution was diluted by adding from four to eight times its volume of water. The poisoned water could be observed at the surface for several minutes, even in muddy water, by its milky appearance.

In order to lay a curtain of poison from surface to bottom in the deep waters encountered in the Coosa River, a hand pump fitted with a 25-foot length of garden hose was used. The hose was plugged and weighted at the lower end and holes were made several inches apart in the lower 2 feet. The poison was distributed from a boat rowed slowly over the course to be followed. While one man operated the pump, a second man repeatedly lowered the delivery end of the hose to the bottom and drew it back nearly to the surface. The movement of the boat and the raising and lowering of the hose were timed to produce a nearly solid wall of poisoned water. In shallow water no elaborate measures were necessary to insure uniform vertical distribution of the poison. Where it was possible to wade, several persons were given buckets containing poison and were stationed at intervals along the line on which the poison was to be laid. At a signal they all commenced to release their poison and move along the line in the same direction thus achieving the desired result of sending an unbroken curtain of poisoned water downstream.

TABLE 5.—*Numbers and weights of fish collected by rotenone poisoning in six samples at Wood's Farm and Willingham's Trap—weights expressed in pounds.*

Sample number[1]	Depth of river (feet)	Date	Gallons 5 percent rotenone	Number of fish	Weight of fish
1	16	August 29	0.5	303	9.00
2	20	August 29	1.0	557	17.06
3	25	August 30	2.0	988	31.12
4	3	August 30	4.0	551	115.19
5	2	September 3	5.0	548	266.12
6	17	September 6	1.0	450	3.60

[1] Samples 1, 2, 3, and 6 were all taken in the deep water near the Wood's Farm site. Sample 4 was taken in a shallow channel about 150 feet wide and 1,500 feet long about 2.4 miles upstream from the Wood's Farm site. Sample 5 was taken in a similar channel 150 feet wide and 2,000 feet long immediately upstream from the permanent fish traps at the Willingham site.

In each of the two rotenone samples in shallow water (samples 4 and 5), stop nets were set across the downstream end of the channel (Table 5), but in both cases the accumulation of fish, dead leaves, and other debris caused these nets to be carried away by the current before the operation was completed.

Although no test fish were placed in the path of the poisoned water, some idea of the extent of the effect of the poison was obtained from observations made at each operation. The quantity of poison, its method of application, and its rate of mixing with the river water are all interacting factors which determine the effectiveness of the poison and which are difficult to assess. The drifting of distressed and dead fish with the current made casual observations uncertain. However, reports of dying fish came from as far as 2 miles downstream from the sampling operation at Willingham's. Less poison was used in the other poisoning operations, and in the deeper water the effects were not noticed for more than one-half to three-quarters of a mile downstream.

Because there was a wide range in the sizes of fish taken, catches were compared by weight as well as number (Table 6). When the deep water collections (samples 1, 2, 3 and 6) are compared with those from shallow water (samples 4 and 5), no significant differences can be detected although the channel catfish appears to be somewhat more abundant in shallow than in deep water. The fact that the shallow water collections contained a greater number of species than those from deep water may be the result of a more complete pick-up. One feature common to all samples is the predominant position occupied by the freshwater drum. The channel catfish ranks second or third in five out of the six samples, the gizzard shad second or third in three, and the flathead catfish second or third in two. Redhorse suckers (*Moxostoma poecilurum*) and chubs (*Hybopsis hyostomus*) are also relatively important fish, the latter species being quite abundant in the deep-water samples. Smallmouth buffalo and white crappie were completely absent in the samples.

TABLE 6.—*Species composition of six samples collected with rotcnone — expressed as percentage of total number and total weight in each sample.*

Species	1		2		3		4		5		6	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Lake Sturgeon *Acipenser fulvescens*	...	...	...	...	...	...	...	...	0.2	0.7	...	...
Longnose Gar *Lepisosteus osseus*	...	...	...	...	0.1	0.2	...	...	...	...	...	...
Mooneye *Hiodon selenops*	...	...	...	...	...	...	0.2	*	1.5	1.5	0.2	0.1
Gizzard Shad *Dorosoma cepedianum*	0.6	6.5	1.8	7.4	3.7	3.8	2.9	3.3	13.1	18.7	0.7	21.7
Redhorse *Moxostoma poecilurum*	1.0	25.1	0.7	2.9	...	...	1.6	5.1	4.0	4.8	0.7	0.7
Black Redhorse *Moxostoma duquesnii*	...	...	...	...	...	...	0.4	0.3	...	...	...	...
Spotted Sucker *Minytrema melanops*	...	...	...	...	...	...	...	...	0.9	3.0	...	...
Chub *Hybopsis hyostomus*	63.0	7.5	51.5	6.9	30.3	1.0	16.5	0.5	0.1	*	40.7	10.0
Shiner *Notropis stilbius*	13.5	0.6	21.2	1.2	14.7	1.1	12.3	0.3	16.1	0.1	20.4	3.6
Spot Tail *Notropis stigmaturus*	0.6	0.1	2.7	0.7	...	...	2.0	0.1	1.6	*	0.9	0.9
Channel Catfish *Ictalurus lacustris punctatus*	15.5	14.2	14.0	3.4	28.6	12.6	21.4	18.6	25.5	20.8	16.4	10.9
Blue Catfish *Ictalurus furcatus*	...	...	0.2	0.6	9.8	7.6	3.6	3.6	0.4	0.8	0.2	2.7
Flathead Catfish *Pilodictis olivaris*	...	...	1.8	4.2	4.4	13.7	4.5	5.1	2.6	3.3	0.4	0.5
Madtom *Schilbeodes leptacanthus*	...	...	...	...	...	...	0.5	*	4.2	*	...	...
Blackstripe Topminnow *Fundulus notatus*	...	...	...	...	...	...	0.2	*	...	...	...	...
Logperch *Percina caprodes*	...	...	0.4	0.1	...	...	0.4	*	...	...	...	...
Miscellaneous Darters	...	...	1.1	0.1	0.2	0.5	0.7	0.2	0.9	*	...	...
Yellow Pikeperch *Stizostedeon v. vitreum*	...	...	0.2	0.3	...	...	0.5	0.5	0.4	0.3	0.2	2.4
Spotted Black Bass *Micropterus punctulatus henshalli*	...	...	0.4	2.1	0.1	0.7	1.6	1.8	4.9	4.6	0.9	0.4
Green Sunfish *Lepomis cyanellus*	...	...	...	...	...	...	0.7	0.1	...	...	1.1	0.5
Longear Sunfish *Lepomis m. megalotis*	...	...	0.5	0.8	0.6	1.4	1.6	0.5	0.6	*	0.4	1.4
Bluegill Sunfish *Lepomis m. macrochirus*	...	...	...	...	1.1	0.7	0.9	0.5	0.6	0.1	3.1	6.8
Rock Bass *Ambloplites rupestris*	...	...	...	...	...	...	0.4	*	...	...	...	...
White Bass *Lepibema chrysops*	...	...	...	...	0.1	0.3	...	...	...	...	...	...
Freshwater Drum *Aplodinotus grunniens*	5.6	45.9	3.6	69.3	6.5	56.9	27.0	59.5	22.3	41.1	13.6	37.5

* = less than 0.1 percent.

TABLE 7.—*Catch of Willingham's fish traps, July 5 through August 27, 1949—expressed as total number and weight of each species and percentage of total number and weight.*

Species	Number of fish	Percentage of total number	Estimated weight (pounds)	Estimated percentage of total weight
Smallmouth Buffalo *Ictiobus bubalus*	36	27.3	108.7	40.1
Blue Catfish *Ictalurus furcatus*	41	31.1	97.3	35.9
Freshwater Drum *Aplodinotus grunniens*	43	32.6	45.95	16.9
Channel Catfish *Ictalurus lacustris punctatus*	6	4.5	7.5	2.8
Redhorse Sucker *Moxostoma poecilurum*	3	2.3	3.8	1.4
Blue Sucker *Cycleptus elongatus*	3	2.3	7.5	2.8
Totals	132	....	270.75[1]	....

[1] Actual catch was 266.0 pounds.

CATCH OF THE PERMANENT FISH TRAPS

Permanent fish traps are legally operated at several points along the Coosa River. Two traps located at Willingham's furnished supplementary samples of the fish in that region. These fish traps consist of v-shaped rock and log dams about 4 feet in height which direct the current of the stream onto a series of slatted descending steps. Observations on these traps extended from July 5 through August 27, 1949. During this period the traps were checked on 39 different days, but fish were taken on only 27 days (Table 7). The efficiency of these traps is markedly influenced by water level. During one period of high water there were 11 days (July 17-27) when a total of only two fish (a buffalo and a drum) was taken. While the total weight of each day's catch was known, the distribution of this weight among the species was not always recorded so the weight composition of the catch was estimated from that fraction of the catch that was weighed by species (45 percent).

COMPARISON OF SAMPLING METHODS

In comparing the results of these sampling methods it seems advisable to deal with each of the more important species separately and compare the sampling methods as applied to each at the two sites of operation (Figure 2).

Gizzard Shad.—As far as net and basket catches were concerned, the gizzard shad was found only in shallow water although rotenone revealed its presence in deep waters as well. This species was far more important than any of our sampling methods indicated. Large numbers were observed at the surface in each rotenone operation but relatively few of them were picked up before they sank and were lost.

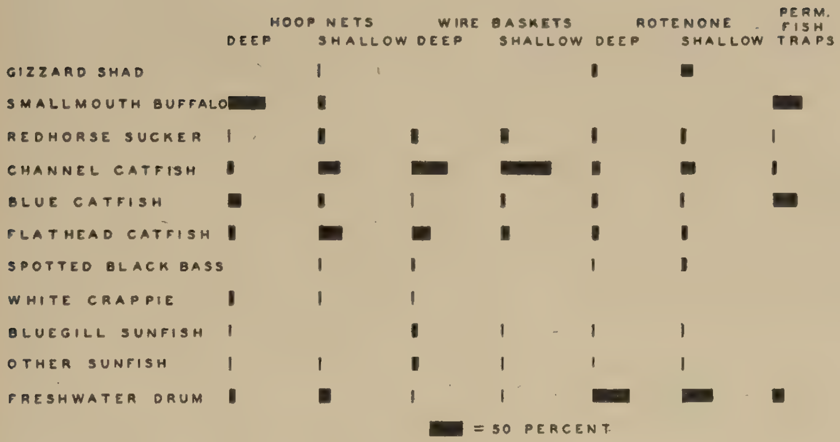

FIGURE 2.—Percentage composition by weight of important species of fish taken by all sampling methods.

Smallmouth Buffalo.—The smallmouth buffalo was the most important fish in the catch of the hoop nets in deep water while it was of only minor significance in the shallow water catches. The smallmouth buffalo did occur in the shallow water in fair abundance, however, since it made up the greater part of the catch of the permanent fish traps. The absence of the smallmouth buffalo from wire-basket catches was to be expected because of the large size of this species. Its failure to appear in any of the rotenone samples cannot be explained satisfactorily. This species is evidently much more resistant to rotenone than any of the other species encountered. Possibly individuals that were in the areas poisoned were not seriously affected and escaped.

Channel Catfish.—Hoop-net and wire-basket catches and poisoning indicated that the channel catfish was more abundant in shallow water than in deep water. However, at the permanent fish-traps site, where, by all other indications, the channel catfish was most abundant, it made up but a very small fraction of the trap catch.

Blue Catfish.—The blue catfish was slightly more important than the channel catfish in the catches of the deep water hoop nets, but less abundant in the catches of hoop nets set in shallow water. The larger average size of this species prevented it from being an important constituent of the basket catches at either site. Its size might also have been a factor in making it much scarcer than the channel catfish in all rotenone samples. The blue catfish ranked far above the channel catfish in the catch of the permanent fish traps in spite of the fact that the latter was known to have been much more abundant in that area. The permanent fish traps seem to be highly selective for blue catfish.

Flathead Catfish.—The flathead catfish was scarce in deep-water net catches but ranked highest in the shallow-water net catches. Like the blue catfish, its average size was greater than that of the channel catfish and for this reason it was also probably less susceptible to rotenone and wire baskets. This species was not taken in the permanent fish traps although it was known to be abundant in the vicinity.

Freshwater Drum.—The freshwater drum made up a larger part of the catch of hoop nets in shallow water than in deep water, and it ran a close third in the catch of the permanent fish traps. Since this fish appeared to be particularly sensitive to rotenone and since it remained afloat after death for some time, it predominated in all rotenone samples and tended to diminish unduly the relative importance of the other species taken in this way.

Game and Pan Fish.—It would appear that, with certain exceptions, game and pan fish were quite scarce in this section of the Coosa River (Figure 2). However, interviews with anglers and angling by the author indicated the presence of game and pan fish in spots where they were not taken by other methods, and suggest the inadequacy of the sampling of these species. The absence of white crappie in the rotenone samples testifies to this inadequacy, because this species was known to be present in some numbers in the deeper water. The fact that spotted black bass were taken in fair numbers in the rotenone sample at Willingham's while other centrarchids normally found with it such as the rock bass and longear sunfish were nearly absent is not readily explained.

The carp, although not present in our samples, is known from impoundments in the Coosa drainage and is probably present in the river at other times of the year. Two black basses, the largemouth and the redeye, were to be expected in addition to the spotted bass, but neither of these was encountered in the river proper. Among the fish taken rarely but known to be fairly abundant was the longnose gar which was observed on a number of occasions but was represented in our samples by only 10 adults taken in hoop nets and one young taken with rotenone.

ACKNOWLEDGMENTS

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A TRAP FOR THE CAPTURE OF FISH AND OTHER ORGANISMS MOVING DOWNSTREAM

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ABSTRACT

In connection with a study of salmon and trout in a Swedish river, a trap was developed which has proved successful in capturing, unharmed, downstream-moving fish and other organisms. It consists of a fine-meshed screen set at a slight angle to the horizontal, on which water falls after passing over a weir. Fish and other solid particles are caught by the screening and washed down the incline into a trap placed below the lower end of the screen. The device is comparatively simple in design and construction, operates efficiently under widely varying amounts of flow, and may be left untended for periods up to 3 weeks in duration.

The Swedish Salmon and Trout Association is an organization chiefly concerned with the restoration of rivers to production of Atlantic salmon, *Salmo salar*, and sea-run brown trout, *Salmo trutta*. In Kavlinge River of southern Sweden these species have been extinct for many years and there is practically no natural supply of them in the region. Salmon and trout fry, therefore, have been planted by various methods. It has been the policy to restrict the planting of fry, for the most part, to the smaller streams of the Kavlinge watershed. By using the brooks of moderate size, it was thought that the behavior of introduced fish and the results of the planting could be observed more easily and that the value of these waters as producers of fish could be appraised. The results obtained have demonstrated the wisdom of this approach to the problem.

Early in the study it became necessary to find out something about the down-stream movements of salmon and trout during the early stages of their life. Existing trapping methods seemed to be of little use since the trapping of the fish had to begin almost immediately after planting. A trap with the following qualifications was needed: (1) it should trap all fish, moving downstream, regardless of size; (2) it should not injure the fish even if the trap were not attended very frequently; (3) it should be able to accommodate flows varying from a mere trickle up to 1 cubic meter per second (approximately 35 C. F. S.) or more, since the brooks in which the planting was done were mountain streams subject to very heavy floods; (4) it should be so constructed that even in times of heavy floods laden with debris it would not clog; and (5) it should be possible to leave the trap without any attention for rather long periods, at least 3 weeks.

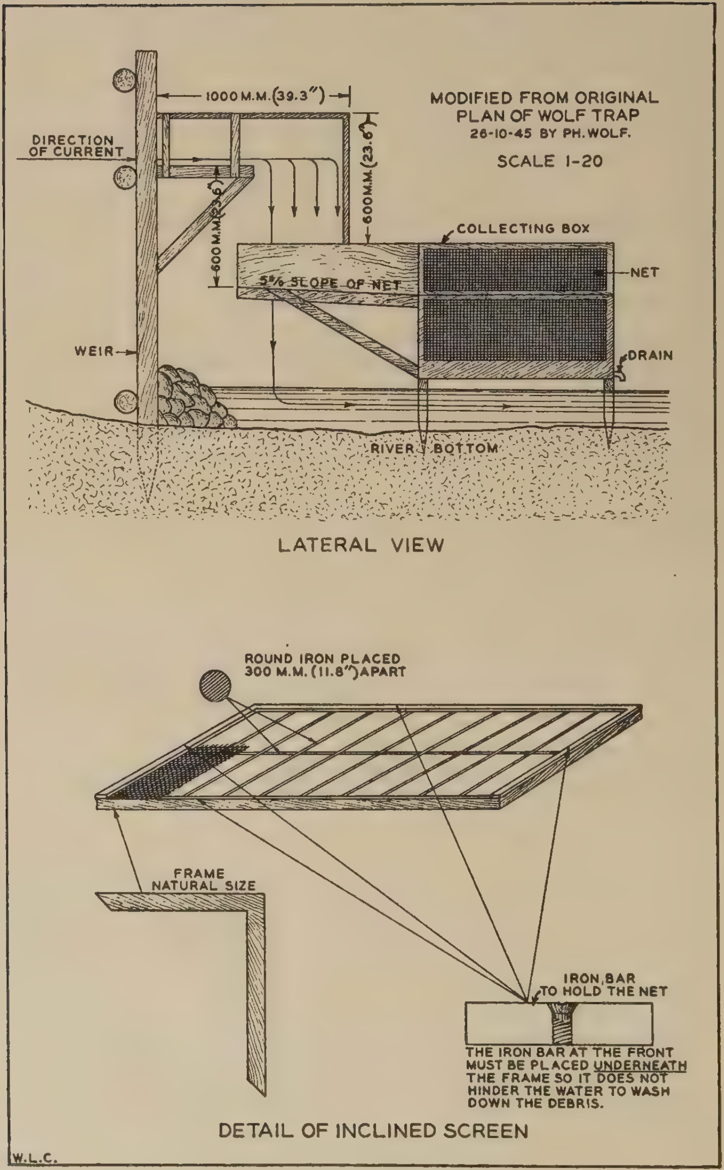
MODIFIED FROM ORIGINAL
PLAN OF WOLF TRAP
26-10-45 BY PH. WOLF.
SCALE 1-20
1000 M.M. (39.3")
600 M.M. (23.6")
600 M.M. (23.6")
DIRECTION OF CURRENT
COLLECTING BOX
NET
5% SLOPE OF NET
WEIR
DRAIN
RIVER BOTTOM
LATERAL VIEW
ROUND IRON PLACED
300 M.M. (11.8") APART
FRAME
NATURAL SIZE
IRON BAR
TO HOLD THE NET
THE IRON BAR AT THE FRONT MUST BE PLACED UNDERNEATH THE FRAME SO IT DOES NOT HINDER THE WATER TO WASH DOWN THE DEBRIS.
DETAIL OF INCLINED SCREEN
W.L.C.

FIGURE 1.—Diagram showing details of construction and installation of inclined screen trap.

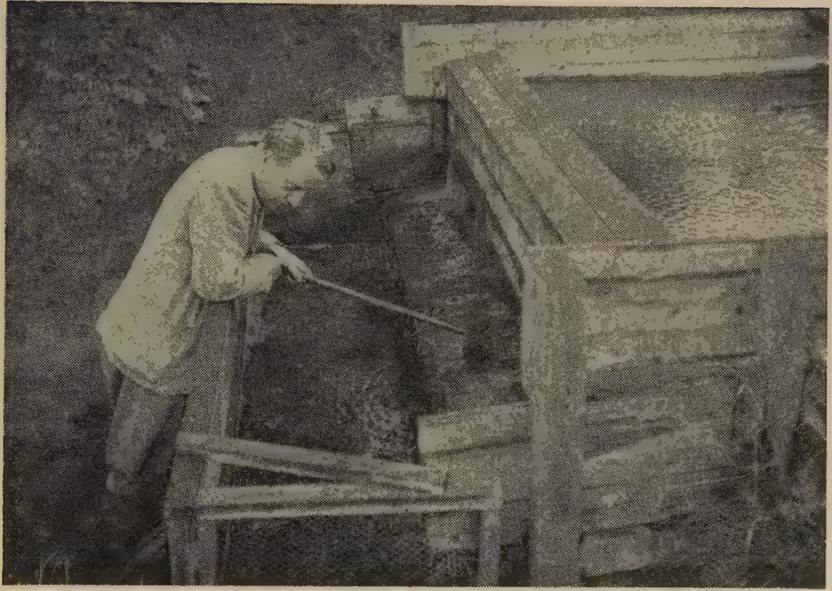

FIGURE 2.—A Wolf trap in a small brook in Sweden. The brush the man holds rests on the screen. He is leaning his elbows on the coarse screen which is above the fine screen on the sides of the box. Looking down into the box.

A trap embodying these qualifications was developed (Wolf, 1946). The method by which the trap was constructed is very simple but has a basic principle which, so far as the writer knows, has not been used before. A fine-meshed screen set at a slight angle to the horizontal below a vertically falling current of water will catch fish and other solid particles while allowing most of the water to pass through. Enough water is retained on top, however, to wash the solids down the slope into a container which holds water.

The trap (Figure 1) must be built in connection with a weir which will impart to the water the fall necessary to pass it through the screen. The weir can follow any design so long as it creates a sufficient head. In some cases, the water leaving the weir in a horizontal direction must be forced down vertically by a board placed across its path, to prevent too much of it from being splashed out into the container (Figure 2). In other cases this is not necessary (Figure 3).

The height from which the water should fall on the screen should not be less than 550 millimeters (21.7 inches) or better 600 millimeters (23.6 inches). Less height results in too little water passing through the screen while a higher drop causes the water to hammer on the structure with too much force, resulting in rapid wearing out of the screen and in injuries to the fish. The screening should be of phosphor-bronze, 24 meshes to the inch. Any less resistant material will wear out rapidly in the continually falling water. Stainless steel might be just as good or better but the cost may be too high.

The collecting box can be made in any reasonable size depending on the amount of fish or debris it is to hold. The same screening as mentioned above is used for the sides, while a coarser screen may be used for the upper part since its main purpose is to prevent the fish from jumping out of the box. The bottom is framed up with boards so that it will hold sufficient water to keep the trapped fish alive. Any fish coming downstream will be safely caught in the trap (Figure *2*) and

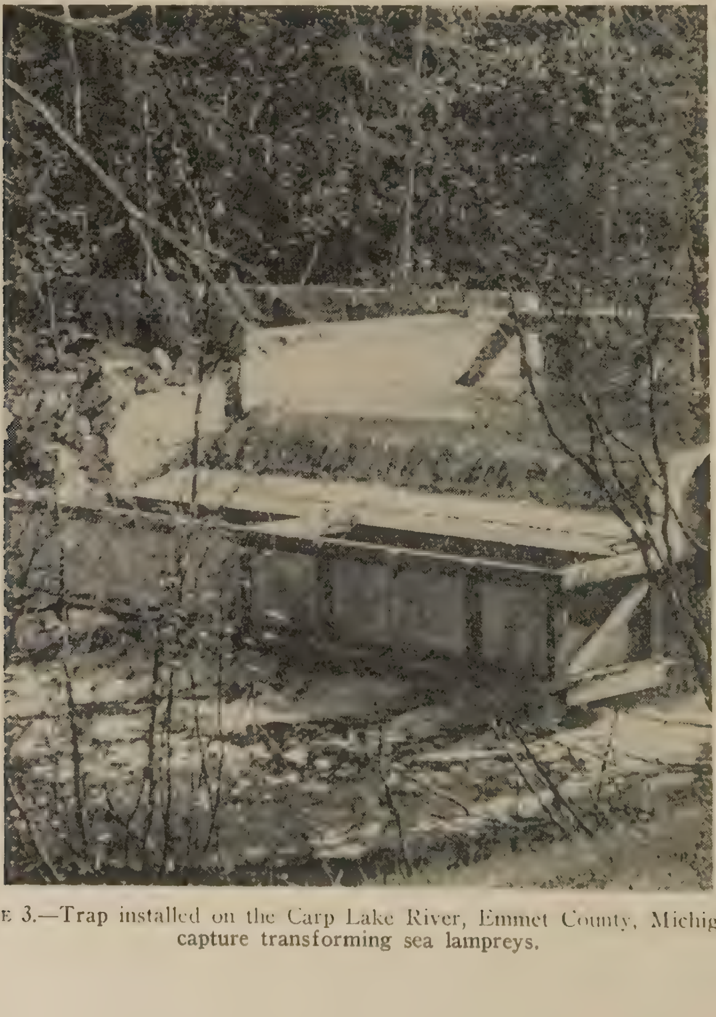

FIGURE 3.—Trap installed on the Carp Lake River, Emmet County, Michigan, to capture transforming sea lampreys.

kept alive by the excess water which flows from the screen into the container. A screened drain in the bottom can be opened to remove this water when emptying the trap. In experiments it has been found helpful to shade the upper part of the trap (the weir) by bushes or other means since salmon and trout fry enter with less hesitation, even in daytime, when shade is provided.

The trap will catch not only fish but also every other animal as well down to 0.3 millimeter in smallest dimension. The living components of the drift can thus be studied quantitatively and it may be remarked that surprising numbers of animals enter this "counting station." At certain times, even in small brooks, some hundreds of thousands of food animals have been caught in 24 hours. A further use suggested is at fish rearing stations for catching natural food. The trap has such a capacity and takes so little care that when set up in a productive small brook it may well provide a considerable amount of fish food. It can also be used advantageously at the outlets of reservoirs and dams, where it is possible to capture every animal leaving the impoundment.

The chief value of the trap lies in its ability to take fish of any size without injury. Provided the inlet to the trap is not too unnatural, the fish will enter it, and once they are well inside there is no possibility of escape. One disadvantage is that the trap can be used only where it is possible to obtain the necessary head of water. The total drop required from the upper to the lower water level cannot be much less than 1 meter, preferably more, depending upon how deep a collecting box is required.

In addition to its initial use in Sweden the trap has also been employed in Michigan, U. S. A., and in British Columbia, Canada. In Michigan, it has been used in the Carp Lake River (Figure 3) for studying the migratory habits of young sea lampreys, *Petromyzon marinus*, and in Hunt Creek for studying the downstream movements of the brook trout, *Salvelinus fontinalis*. In British Columbia it was installed in a small river, Port John Creek, to catch the sea-migrating pink salmon fry, *Oncorhynchus gorbuscha*. In all cases good results have been reported. Other uses of the trap are also planned in other parts of the world.

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IS THERE A HARVESTABILITY DIFFERENTIAL IN FISH?[1]

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Abstract

An attempt is made to demonstrate that the availability of fish to the angler in TVA reservoirs is not strictly correlated with their relative abundance. Crappie, which are subjected to much heavier fishing pressure than bass, are caught at a much lower rate as demonstrated by creel census and return of tagged fish. It is suggested that it may be possible to calculate a factor for differential availability of fish.

Introduction

The question of differential availability of fish of different species to anglers without regard to relative population density has interested both sportsmen and fishery investigators. Most fishermen know that the ease with which they take one or another species of fish varies greatly from day to day, but we are interested in determining whether or not an availability differential exists between species, and if so, whether it is measurable.

If the existence of such a factor can be shown and a method for its determination demonstrated, its importance and practical application are considerable. Available evidence indicates that there is no need for a closed season on Tennessee Valley Authority impoundments, but in waters where such regulation is considered desirable, a closed season on the larger predatory game-fish species, or a period during which the use of artificial bait was prohibited, might be preferable to a general closed season. In this paper we shall present evidence that suggests an affirmative answer to the question.

Source of Material

The material presented herein is derived from creel census and fish-harvesting studies conducted on Norris and Cherokee reservoirs (Tennessee) for several years. In their regular contacts, creel census clerks were instructed to ask each fisherman what kind of bait was used during the course of the day's fishing. However, since numbers and weights of fish caught were more important than the type of bait used, the latter item was sometimes neglected, particularly during rush hours.

Fortunately, one census-taker on each reservoir consistently recorded the type of bait and these data appear below. Qualitatively, the fishing

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[1] Published with permission of the Tennessee Valley Authority.

TABLE 1.—*Number of individual fishing trips and total catch of black bass and crappie, Norris Reservoir, 1947-1949, summarized by species.*[1]

Year	Type of fishing					
	Natural bait			Artificial bait		
	Number trips	Number black bass	Number crappie	Number trips	Number black bass	Number crappie
1947	1,088	315	2,486	639	661	56
1948	1,069	209	1,801	311	229	34
1949	1,199	424	2,371	260	207	20
Total	3,356	948	6,658	1,210	1,097	110
Ratio bass to crappie	....	1	7.04	....	9.97	1

[1] Several other species appeared but the two groups considered here predominated in the catch from both reservoirs.

observed at each of these stations is considered to be representative of the whole reservoir on which it is situated.

Results of 4,566 individual fishing trips out of Rogers Dock on Norris Reservoir from 1947 through 1949 (Table 1) were recorded. The information for bass *(Micropterus salmoides* and *M. dolomieu)* and crappie *(Pomoxis nigro-maculatus)* was converted into average catch per 100 individual trips (Table 2). Through many hundreds of contacts with sports fishermen we have reached the conclusion that, locally at least, natural bait fishing (with live minnows) is directed primarily at crappie while artificial bait fishing (mainly with plugs) is aimed at black bass.

On Norris Reservoir 73.5 percent of the fishing was for crappie, while 26.5 percent was for bass.[2] While fishing pressure on the crappie was nearly three times that on the bass, fishing with natural bait for the former species took seven crappie for each bass. On the other hand, the pressure on the bass was only one-third that on the crappies, but the fishing with artificial bait took 9.97 bass for each crappie. Tag returns from harvesting studies covering the same period (1947, 1948, and 1949) were 20.9 percent for bass and only 12.4 percent for crappie (Manges, 1950). It therefore appears that roughly three-fourths of the

TABLE 2.—*Average catch of bass and crappie per 100 individual fishing trips, Norris Reservoir, 1947-1949.*

Type bait	Black bass	Crappie	Total
Natural.................	28.24	198.30	226.54
Artificial.................	90.82	9.18	100.00

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[2] Data on trips where both types of bait were used are not included because of the difficulty in determining what part of the day's fishing was devoted to each.

TABLE 3.—*Number of individual fishing trips and total catch of black bass and crappie, Cherokee Reservoir, 1947-1949, summarized by species.*[1]

Year	Type of fishing					
	Natural bait			Artificial bait		
	Number trips	Number black bass	Number crappie	Number trips	Number black bass	Number crappie
1947	3,084	441	23,942	949	711	1,229
1948	1,222	76	3,841	927	306	1,216
1949	1,535	631	5,140	1,131	448	1,364
Total	5,841	1,148	32,923	3,007	1,465	3,809
Ratio bass to crappie	....	1	28.68	....	1	2.6

[1] Several other species appeared but the two groups considered here predominated in the catch from both reservoirs.

fishing effort, directed at crappies, harvested 12.4 percent of the crappie population and took, incidentally, only one bass for every seven crappies. One-fourth of the fishing effort, directed at bass, harvested 20.9 percent of the bass population and took, incidentally, only 1 crappie for every 10 bass.

These results seem to indicate that the larger predators (bass) were more available to anglers than the crappie. It might be argued that mortality from tagging may be greater in crappie than in bass, but Miller (1951) working in Alabama has shown that there is no greater mortality for tagged than for untagged crappie during the spring when most fish are caught.

On Cherokee Reservoir the creel census covered 8,848 individual fishing trips during the 1947-1949 period (Tables 3 and 4). Here, as in Norris Reservoir, the fishing was mostly for crappies. On 66 percent of the trips natural bait was used and on 34 percent the bait was artificial. The catch on natural bait was 28 crappie for each bass, while artificial bait took only 3 crappie for each bass. Tag returns from this reservoir for the same period were 9.0 percent for bass and 4.7 percent for crappie (Manges, loc. cit.). Therefore, two-thirds of the fishing effort was directed at crappie, harvested 4.7 percent of the population, and took, incidentally, only one bass for every 28.7 crappie. One-third of the fishing effort, directed at bass, harvested 9.0 percent of the bass crop, and took, incidentally, 2.6 crappie for each bass. In other words, although the bass (artificial bait) fishing effort took approximately three crappie to one bass and harvested 9.0 percent of the bass crop, twice as much crappie (natural bait) fishing, took 28 crappie to 1 bass and harvested only slightly more than half as much of the crappie crop. The difference here is less marked than in Norris Reservoir, and may result from the fact that the crappie population includes both black and white crappie *(Pomoxis annularis)*, and also an unde-

TABLE 4.—*Average catch of bass and crappie per 100 individual fishing trips, Cherokee Reservoir, 1947-1949, inclusive.*

Type bait	Black bass	Crappie	Total
Natural	19.67	563.64	583.31
Artificial	38.72	123.35	162.07

termined part of the artificial bait fishing is directed toward the crappie (trolling with very small plugs). Nevertheless, the larger predators (bass) appear to be taken more readily even though they are subjected to much less angling effort.

The evaluation of a difference in harvestability seems of lesser importance than the establishment of its existence. The foregoing evidence suggests that, in these two bodies of water at least, the larger predators are more available to the angler than the crappie. If this is true for other waters, the chief significance of the principle may be in its application to the solution of what appears to be an ever-increasing problem of over-population of pan-fish species.

ACKNOWLEDGMENTS

The writer is indebted to Dr. R. W. Eschmeyer, until recently his immediate supervisor, for assistance in crystallizing and defining the question; to C. J. Chance, L. A. Krumholz, and W. W. Hassler for constructive criticism in preparing the manuscript, including mathematical analysis; to D. W. Yambert and Mrs. Cordelia Pointer for compilation of the basic data; and to a number of creel census-takers for recording the original information.

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RESULTS OF INCREASED FISH HARVEST IN LOST ISLAND LAKE

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ABSTRACT

Lost Island Lake in northwest Iowa is a shallow glacial lake with a surface area of 1,260 acres. It is an important fishing lake, and management practices have centered around the maintenance of fishing for the black bullhead (*Ameiurus m. melas*). Following a partial freeze-out in 1940-41 a large year class of black bullheads was produced. The growth of this year class was observed from 1941 to 1950. By 1946 it was apparent that the growth was slow and stunting had occurred. This condition was coupled with the presence of a large carp (*Cyprinus carpio*) population and a low volume of potential food organisms. Recommendations were made to harvest as many carp as possible and to remove the catch limits on bullheads.

Carp removal ranged from 80.8 pounds per acre in 1946 to 23.6 pounds per acre in 1950. Creel census revealed that a minimum of 842,000 bullheads were harvested by hook and line during the 3-year period from 1946 through 1948, with a catch of 5.2 fish per hour in 1946 and 1947. The harvest changed from a large number of small fish per hour in 1946 to a smaller number of large fish in 1950.

A marked increase in the growth rate of the bullheads occurred following the 1948 season. The average volume of fish-food organisms, principally chironomid larvae, per unit area on the lake bottom increased in late 1948 and continued through 1950.

INTRODUCTION

Lost Island Lake, in Palo Alto and Clay Counties, Iowa, is one of the principal bullhead lakes in the state. It has a maximum depth of about 12 feet at crest elevation, gradually sloping sand and glacial boulder shores, mud bottom, and an area of 1,260 acres. Fish management practices on Lost Island Lake have for many years emphasized the maintenance of good fishing for the black bullhead *(Ameiurus m. melas)*, a species which is in great demand by the Iowa angler. In addition to bullheads the lake has a moderate-sized population of yellow pikeperch or walleye *(Stizostedion vitreum)*, northern pike *(Esox lucius)*, yellow perch *(Perca flavescens)*, and crappie *(Poxomis nigromaculatus* and *P. annularis)*. Carp *(Cyprinus carpio)* have been present in varying densities.

This lake has had two severe winter kills of fish in recent years. One of them occurred during the winter of 1935-1936. After this kill the lake was stocked with bullheads each year until another heavy kill occurred during the winter of 1940-1941. Reproduction from the few adults which survived this kill was so prolific that no further stocking has been necessary. The establishment of the very strong 1941 year class and the subsequent failure of reproduction until 1947 provided an excellent opportunity to check the effects of crowding and subsequent population reduction on the rate of growth of the bullhead.

Routine lake surveys carried on from 1941 to 1950 provided material for analysis of growth and population changes during the period. Since no additional year classes were added to the lake until 1947, it has been possible to follow accurately the growth history of the individuals in the 1941 class (Table 1). More than 5,000 bullheads of the 1941 year class which were fin-clipped for a population study in the spring of 1948 have proved of value in following that class.

During the period from 1941 to 1945 the 1941 year class showed little growth increment (Table 1). Since there was no increase in the size of the bullheads from 1944 to 1945, an intensive study was initiated in 1946, to investigate the reasons for this slow growth. Bottom sampling revealed that there was a very low production of fish-food organisms. Examination of the carp population indicated that it was very large, and comparison of the stomach contents with that of bullheads in 1947 (Table 2) suggested that it was competing with bullheads for food. Stomach analyses of carp and bullheads from other Iowa Lakes, particularly East Okoboji, Spirit, Diamond, and Welch indicate that the food of these two species is similar. In view of the apparent overcrowding of bullheads and the competition from carp it was recommended that as many carp as possible be removed by seines and traps and that the daily catch limits on bullheads be completely removed.

TABLE 1.—*Annual average total lengths (inches), weights (ounces), and numbers per haul of the 1941 year class of black bullheads in Lost Island Lake, 1941-1950. Average condition factors are for 1946-1950.*

Year	Average total length	Average weight	Average number per haul	Average[1] k
1941	1.5	0.1	39,000	....
1942	2.2	2.2	10,000	....
1943	....	....	....	....
1944	6.0	2.5	960	....
1945	6.0	2.5	1,312	....
1946	7.2	3.3	657	2.446 (20)[3]
1947	8.0	4.0	364	2.423 (103)
1948	8.5	4.8	108	2.373 (114)
1949	9.7	9.4	16	3.074 (107)
1950	10.4	10.1	(Pond nets)[2]	2.756 (48)

[1] $k = \frac{W\ 10\text{-}5}{L^3}$

[2] where W = weight in grams and L = standard length in millimeters.
Survey seine caught no 1941 year class fish; data supplemented by pond net catches.

[3] Number of bullheads used in determination of k.

TABLE 2.—*Food items taken from the stomachs of 119 bullheads and 16 carp from Lost Island Lake in 1947 expressed as percentage of stomachs containing each item.*

Item	Bullheads	Carp
Invertebrates	97	100
Insects	55	100
Ephemeroptera	2	58
Hemiptera	20	2
Coleoptera	3	...
Trichoptera	5	66
Diptera	37	100
Crustaceans	60	92
Entomostraca	60	92
Oligochaetes	2	...
Vertebrates	3	...
Fish	1	...
Frogs	1	...
Plants	55	100
Algae	2	83
Debris	55	100
Number stomachs with food	62	13
Total volume of food (cubic centimeters)	35.4	203.0

POPULATION CHANGES

Carp removal.—No rough fish removal operations had been carried on in this lake during the 10-year period preceding the fall of 1945, and in consequence a large carp population had developed. A carp removal program was started in the spring of 1946 with the construction of a permanent trap at the Barringer Slough inlet of Lost Island Lake. This trap proved to be an effective means of removing fish and has been in operation each year since its construction. The largest catches of carp were made in 1946 and 1947 when 80.8 and 54.3 pounds per acre were taken. Although the total yield dropped after 1947, the average weight of the fish increased steadily from 1947 to 1950 (Table 3).

TABLE 3.—*Total weight (pounds) of carp removed, pounds per acre, average weights and condition factors of carp from Lost Island Lake, 1944-1949.*

Year	Total removed	Pounds per acre removed	Average weights[2]	Average k
1944	....	....	1.8	....
1945	24,344	19.3	2.0	....
1946	113,245	80.8	2.0	....
1947	68,538	54.3	2.3	2.50 (93)[1]
1948	30,785	25.2	4.5	....
1949	24,492	19.4	6.0	....
1950	29,870	23.6	10.0	2.89 (38)[1]

[1] Number of carp used in determination of k.

[2] Average weight in pounds obtained from survey data 1944, weights in other years from rough fish crew.

TABLE 4.—*Summary of fish caught by anglers from Lost Island Lake, May 15 to July 1, 1946-1950.*

Species	1946	1947	1948	1949	1950
Crappie	0	0	5	2	250
Yellow perch	56	51	285	19	22
Northern pike	23	50	131	478	366
Walleye	130	359	760	106	2,266
Largemouth	0	0	0	2	0
Bullhead	100,111	169,344	346,954	51,482	87,646
Total Fish	100,320	169,804	348,135	52,089	90,554
Total weight (pounds)	21,157	43,639	107,035	32,487	63,724
Average weight (pounds)	0.211	0.257	0.307	0.624	0.704
Number of anglers	3,378	7,495	25,917	10,842	12,753
Fish per angler	29.6	22.6	13.4	4.8	7.0
Fish per hour	5.2	5.2	2.9	0.9	2.0
Pounds per hour	1.07	1.34	0.89	0.56	1.41

Bullheads removed by anglers.—To evaluate effects of the new management upon anglers' catches, a creel census has been conducted from 1946 through 1950, (Rose 1947, 1948). In 1946, 1947, and 1948 the census was conducted during most of the open season but in 1949 and 1950 it was discontinued on July 1. Although more than 842,000 bullheads were removed from Lost Island by hook and line during the first 3 years, the comparisons in Table 4 which show catches from May 15 to July 1 do not reflect this total. The 842,000 bullheads recorded in this 3-year period had an average weight of 0.285 pounds and represented an average harvest of 63.5 pounds per acre per year.

Prior to 1946, angling was considered to be very poor by local fishermen. The small bullheads were not desired, especially since only 25 could be taken. With the removal of limits in 1946, the news of phenomenally large catches soon spread and by 1948 the increase in size and quality of the fish attracted thousands of anglers to this lake. Although the number of fish caught per hour dropped markedly after 1947, the average weight of the bullheads increased three times from 1947 to 1950. The catch per hour, in weight also increased and was greater in 1950 than in any previous year.

It is believed that the decline in the size of bullhead catches in 1949 and 1950 resulted, in part, from the closure to angling of the major spawning area of the lake until July 1. In previous years the majority of the early catches were made in this region. During 1950 the catch increased significantly over 1949 and in terms of pounds per acre exceeded all other years except 1948. Walleyes *(Stizostedion vitreum)* have also made significant increases in numbers and the 1950 catch was comparatively good.

CHANGES IN BOTTOM FAUNA

Bottom food organisms, mostly chironomid larvae, were sampled with a Peterson dredge at 9 to 10 regular stations three times each

TABLE 5.—*Number and volume of bottom fauna organisms per square foot of bottom, Lost Island, at various seasons, 1946-1950.*

Year	Month	Number of stations	Average volume (cubic centimeters)	Average number
1946	February	9	trace[1]	2.0
	June	10	0.8	34.7
	November	9	trace[1]	10.7
1947	January	9	0.1	14.8
	June	10	0.1	19.4
	October	10	trace[1]	12.5
1948	February	9	0.1	15.0
	June	10	0.2	26.0
	November	9	0.8	50.0
1949	February	9	0.8	84.4
	June	9	0.4	38.5
	No data			
1950	March	10	0.2	18.7
	July	9	0.5	20.0
	September	9	0.9	23.6

[1] Less than 0.1 cubic centimeters.

year (Table 5). Although the bottom fauna was sparse (less than 1.00 cubic centimeter) at all seasons it was more abundant during the last 3 years and it is believed that this increase is correlated with a decrease in the bullhead and carp populations.

Lost Island Lake supports very little submerged vegetation that would normally harbor additional food organisms. Bottom organisms, therefore, comprise the major source of food. According to Ball (1948) less than 1 cubic centimeter of invertebrates per square foot of littoral zone bottom would not support a growing fish population in Third Sister Lake, Michigan. The Lost Island results suggest a similar relationship between available food and growth rates, but the critical level is apparently somewhat lower than 1.0 cubic centimeter in this lake. In Iowa lakes where it has been found necessary to reduce populations of bottom-feeding fishes such as carp and bullheads, by seines, traps, drainage or otherwise, there is usually less than 0.1 cubic centimeter of organisms per square foot prior to the removal of the bottom-feeding fishes.

DISCUSSION

Some authors (Van Oosten, 1944; Eddy and Carlander, 1940) contend that the control of fish population densities is of considerable importance in maintaining good growth rates but there are few reports on situations in which such control has been attained. Ricker and Gottschalk (1941) report increases in game fishes and significant improvements in environmental conditions in Bass Lake, Indiana, following extensive coarse fish removal. Beckman (1941 and 1943) reported an increased growth rate of rock bass following reduction of densities of the population. Moyle (1949) reported that the removal of 62 pounds per acre of bullheads from Little Elk Lake, Sherburne County, Minnesota, in 1947 resulted in no detectable decrease in the total poundage of bullheads although the weight increased from 5.8 fish per pound in 1946 to 2.5 fish per pound in 1948.

No definite estimate of the decrease in carp and bullhead populations which resulted from the trapping and liberalized fishing can be made. However, the decrease in the catch-per-hour in the bullhead fishing and in the poundage of carp removed by the traps from 1946 to 1948 suggests an appreciable drop in population density. At the same time the bullheads showed a pronounced increase in growth rate, the average size of the carp increased, and the abundance of bottom fauna improved. With the available data it is not possible to correlate these latter changes with the assumed population decrease brought about by the management, but the sequence of events is suggestive of cause and effect.

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THE FOOD OF THE BURBOT *LOTA LOTA MACULOSA* (LeSUEUR) IN LAKE ERIE

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Abstract

This study includes results of stomach examinations of 5,253 burbot captured near various ports along the north shore of Lake Erie from May, 1946, to May, 1947. Variations in major food items in relation to method of capture, season, locality, and the length of the burbot are examined. The major food items were evaluated by volume, number of items consumed, and the number of stomachs containing each item. Each criterion of abundance assisted in the determination of the role of the burbot in the food relationship of fish in the lake. Fish and invertebrates, largely Percidae and crustaceans, constituted the major part of the burbot's diet. Until its third year of life, the burbot feeds extensively on invertebrates, but from its third to fifth years, fish become the predominant food. Larger burbot had more food in their stomachs than did the smaller burbot and they consumed larger fish rather than larger numbers of fish.

More food was found in the stomachs in the winter than in the summer and the percentage of empty stomachs was inversely related to the amount of food consumed each month. This condition may reflect the lower rate of digestion during the winter. Stomachs of burbot caught in pound nets contained more fish and fewer invertebrates than those caught in gill nets. The burbot preyed extensively on such commercial fish as the yellow perch and pikeperch and to a lesser extent on the white bass. Coregonids were rare in the diet, but large quantities of their eggs were consumed. Of the commercially important coarse fish, 1- and 2-year-old sheepshead were common in the stomachs. Through consumption of troutperch, sculpins, logperch, and shiners, the burbot competed for food with carnivorous species, especially the pikeperch. Competition for food between the immature burbot and the yellow perch, pikeperch, sheepshead, and other invertebrate-consuming species was also evident. The most important invertebrates in the diet were gammarids, asellids, mysids, mayflies, and crayfish.

Introduction

The burbot,[1] *Lota lota maculosa,* is believed by fishermen to occupy a key position in the food relationships of fish in Lake Erie. To determine the extent of its importance a food study was conducted from May, 1946, to May, 1947, on 5,253 fish taken from the commercial fishery. Of the large number of published reports on the food of the burbot, none definitely refer to Lake Erie specimens. However, some studies have been made on others of the Great Lakes. Dymond (1928) examined the stomach contents of 64 burbot from Lake Ontario and reported that alewives, cottids, and crayfish were the major food items. Forbes (1888) examined 10 specimens from Lake Michigan and found that 83 percent of the food was fish (one whitefish and the remainder yellow perch) and the other 17 percent was crayfish. Pearse (1921) reported the volume of the food from 10 specimens captured in Lake Michigan as follows: *Leucichthys hoyi*, 40 percent; other fish, 43.8 percent; *Mysis*, 8.9 percent; amphipods, 3.3 percent; Sphaeriidae, 0.6 percent; and bottom mud, 2.8 percent. Van Oosten and Deason (1938) made the most extensive food study of burbot that is known at present. They examined 1,528 stomachs of fish taken from three localities in Lake Michigan from the last of April to the middle of November in 1930, 1931, and 1932. They observed that the fish made up 74.3 percent of the total volume of food. Cottidae and Coregonidae were the predominant forms. Other fish present included Osmeridae, Percopsidae, Percidae (yellow perch), and Gasterosteidae. The number of Coregonidae consumed was relatively small except in northern Lake Michigan. Invertebrates constituted 25.7 percent of the total volume of food. The burbot in this lake is an important competitor of the common whitefish, round whitefish, and possibly some of the chubs by its consumption of small crustaceans (*Pontoporeia, Mysis*) and of crayfish.

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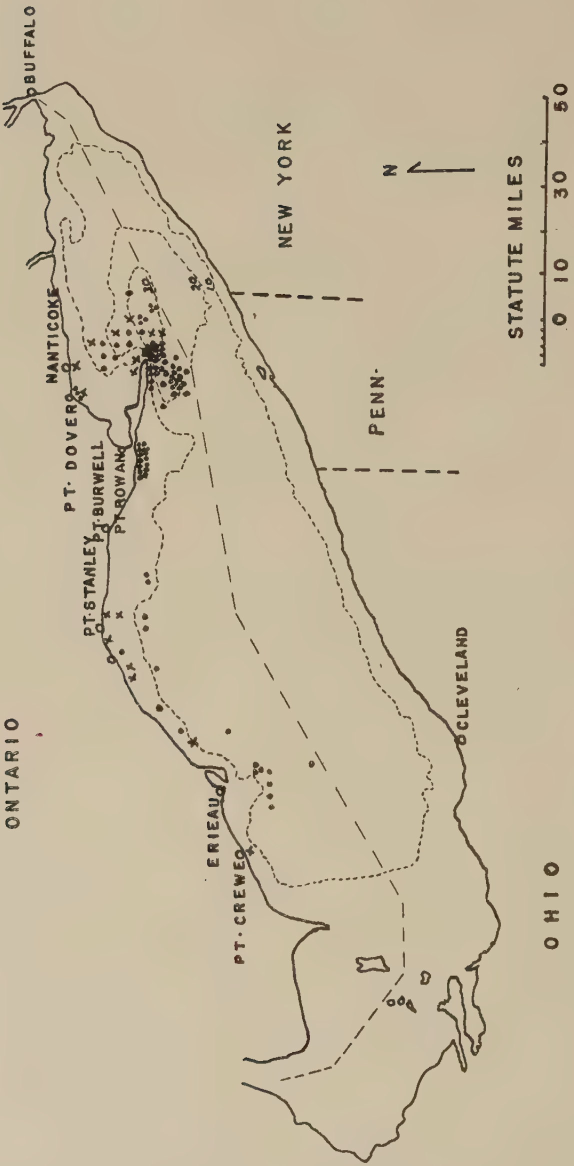
[1] Also commonly called lawyer, ling, eel-pout, dogfish, freshwater cod.

Clemens, et al. (1923 and 1924) examined 242 stomachs of burbot from Lake Nipigon and stated that the bulk of the food for fish 12 to 22 inches long consisted of *Mysis* spp. and ciscoes. In the 1932 Annual Report of the Ontario Game and Fisheries Department, a summary of the food of burbot indicated that in 100 stomachs taken in January from Rideau and Otter lakes only fish were present. Bjorn (1940) examined 144 burbot stomachs from three Wyoming lakes in February and found fish, amphipods, molluscs, and insects.

MATERIALS AND METHODS

Burbot were collected in several localities (Figure 1) along the north shore of Lake Erie by gill, pound, trawl, hoop, and seine nets as well as night lines (Table 1). The principal food analyses were based upon stomach examinations of 4,321 burbot captured by the gill nets of commercial fishermen. These data were augmented by a food study of 37 burbot taken in trawl nets in June and of three specimens taken in hoop nets during February, when there was no commercial fishing. Although gill nets were lifted early each morning, some digestion of the stomach contents occurred before the burbot were removed from the nets. Trawl nets are desirable for the capture of bottom fish for food studies in large lakes because their use eliminates the digestion factor. Eight hundred and thirty-six burbot were captured in pound nets, but in Lake Erie this gear is used only during spring and fall in shallow water. Data from specimens captured in pound nets were kept separate since the burbot prey upon other fish impounded at the same time. Hand seines were employed to provide specimens of the young-of-the-year.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PT. STANLEY
PENN.
CLEVELAND
ONTARIO
ERIEAU
PT. CREWE
OHIO

FIGURE 1.—Map of Lake Erie showing regions of capture of the burbot. One black dot approximates 50 fish and a cross represents 25 or fewer fish.

TABLE 1.—*Number of burbot caught from Lake Erie in different types of gear during each month at various localities—1946, 1947.*

Month	Type of net or line	Locality								Total
		Nanticoke	Port Dover	Port Burwell	Port Rowan	Port Stanley	Erieau	Port Crewe		
May	Pound				341				341	350
	Gill		9						9	
June	Pound				342			2	344	378
	Gill		1						1	
	Trawl		33						33	
July	Pound	1			53				54	1,237
	Gill		1,183						1,183	
August	Gill		767						767	771
	Trawl		4						4	
September	Gill		772						772	783
	Seine		11						11	
October	Pound		2						2	415
	Gill		399						399	
	Seine		14						14	
November	Pound		19						19	329
	Gill		96				214		310	
December	Pound		76						76	353
	Gill			96		90	91		277	
February	Hoop		3						3	3
March	Hoop		23						23	274
	Gill		42			61	148		251	
April	Gill		91			92	67		250	258
	Night lines					8			8	
May	Gill		18			84			102	102
Total	Pound	1	97		736			2	836	5,253
	Gill		3,378	96		327	520		4,321	
	Trawl		37						37	
	Seine		25						25	
	Hoop		26						26	
	Night lines					8			8	

Each fish was measured, weighed, and sexed at the time of capture, and age was determined at the lake or later in the laboratory. The stomachs were tied off, removed, and assigned a number. For the most part stomachs were analyzed in a fresh condition but whenever this was impossible, the contents were completely removed from the stomach, stored in cotton bags, and placed in a 10 percent solution of formalin. When fish were present in the diet, data were secured from these items before they were discarded. All fish in the stomachs were identified, measured, and their volume determined by water displacement. The state of digestion of each fish item in the food was noted. When volumetric determinations were made, food was removed to blotting material in order to absorb the excess juice from the stomach. Recently ingested invertebrates were identified and counted, and their total volume in each stomach was measured. The numbers were estimated by counting aliquot portions of the total volume.

FOOD OF BURBOT

The general analysis of the food of the burbot was made on the basis of volume and number of food items found in the stomachs, and on the number of stomachs containing each type of food. Fish comprised 85.3 percent and invertebrates, 14.7 percent of the total volume of food consumed. However, 47.3 percent of the total number of stomachs containing food included invertebrates alone, 31.8 percent fish alone, and 20.9 percent both fish and invertebrates. These results in general agree with those of Van Oosten and Deason (1938) in that their volume analyses showed that fish was the major food item.

TABLE 2.—*Summary of fish and fish items taken as food by burbot in Lake Erie.*

Food Item	Volume (milliliters)	Number of stomachs containing items	Number of items contained
Food (total)	39,805	2,645	
Fish (all species)	33,964	1,394	2,543
Perca	10,276	182	356
Stizostedion	9,283	264	314
Lepibema	6,277	49	50
Unidentified fish	3,316	861	946
Fish eggs[1]	1,874	138	
Aplodinotus	1,254	62	92
Percopsis	1,056	168	295
Osmerus	285	12	11
Dorosoma	168	18	16
Cottidae	112	89	153
Percina	98	59	93
Notropis	90	56	203
Ambloplites	70	1	5
Coregonidae	44	4	4
Micropterus	10	1	1
Boleosoma	1	1	1
Fish guts		58	
Perca fry			162
Osmerus fry			102
Unidentified fry			65
Stizostedion fry			1

[1] Fish eggs were not counted because numbers were very large.

TABLE 3.—*Summary of invertebrate food items in Lake Erie burbot.*

Food Item	Volume milliliters	Number of stomachs containing items	Number of items contained
Invertebrates (Total)	5,841	1,801	177,857
Crustaceans	4,116	1,480	173,824
Gammarus	1,398	848	71,008
Asellus	1,062	472	58,776
Unidentified invertebrates	1,001	429	
Mysis	968	740	43,560
Cambarus	688	135	590
Mollusca		525	2,952
Lamellibranchs		429	1,201
Gastropods		233	1,751
Valvata tricarinata		84	665
V. sincera		86	545
Amnicola		22	148
Physa		16	16
Lymnea		1	1
Hexapods		368	1,081
Trichoptera		87	433
Hexagenia		73	483
Tipulidae		31	3
Chironomidae		24	18

From the standpoint of volume (Table 2) yellow perch, pikeperch, and white bass were the most important. Sheepshead and troutperch were present in much smaller amounts, as were the crustaceans, *Gammarus, Asellus, Mysis*, and crayfish (Table 3). The fish eggs were eaten largely during early winter. Crustaceans, molluscs, and insects occurred in more stomachs than any of the fish items. Pikeperch, yellow perch, and troutperch were most frequent in occurrence and sculpins, sheepshead, logperch, and white bass were found in 2 percent or more of the stomachs containing food.

When the number of items consumed was considered, yellow perch, pikeperch, and troutperch were most frequent while shiners, sculpins, sheepshead, logperch, and white bass were consumed in smaller numbers. Burbot collected over cisco spawning beds were gorged with eggs so that these numbers were not included. The order of numerical importance of invertebrates was similar to that of volume with the exception that molluscs and hexapods occurred in greater numbers than crayfish.

The volume of food consumed is usually the most significant factor in an analysis of the food of a species. However, in the case of burbot it was believed to be desirable to consider numbers and frequency of occurrence also in order to evaluate the relationship of the burbot to other fishes in the lake. White bass ranked third in the volume but consideration of the other criteria showed that only a few burbot consumed a few large white bass. When this observation was checked, it was found that 60 percent of the white bass consumed were of marketable size and that more than 88 percent of the white bass were taken in 2 months (March and April). The consumption of white bass, therefore, did not appear to be as important as the volume analyses indicated. Troutperch, on the other hand, were an insignificant item in the volume analyses but consideration of numbers and incidence made it apparent that burbot preyed extensively on troutperch throughout the entire year. Emerald shiners were unimportant in both volume and occurrence but these small fish were picked up in great numbers by a limited number of burbot. Since shiners appeared in the diet of specimens taken late in December when relatively few fish were captured, the lack of adequate samples through the winter may have obscured the true significance of the shiner during this period. The occurrence of the shiner, a surface dweller, in the food of a typical bottom feeder is probably explained by the fact that gill-net catches show that burbot may feed near the surface or in shallow water. Consideration of the consumption of fry also indicates that all three methods of evaluation must be employed to determine the significance of the observed predation. From these observations it is apparent that volume of food alone cannot be relied upon to assess the importance of the burbot in the general economy of the fish in Lake Erie.

Relation of Size to Food Consumption

Stomach examination of 23 small burbot during August, September, and October revealed that *Gammarus* and mayflies constitute a staple portion of their diet. However, some very young burbot apparently take fish. At Port Ryerse near Port Rowan, on October 10, 1946, a 90-millimeter burbot was taken with three small fish in its stomach. Although the time of hatching of burbot eggs is not known in Lake Erie, it is believed by Fish (1932) that hatching probably occurs during May and June; this 90-millimeter burbot, therefore, would be about 4 months old.

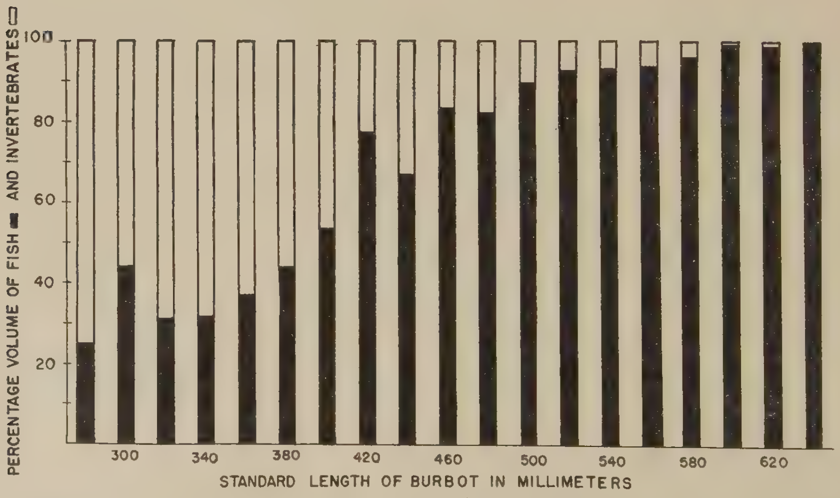

Figure 2.—The volume of fish and other food items in stomachs of Lake Erie burbot of different lengths, expressed as percentage of total stomach volume (solid bar, fish; open bar, other items).

As burbot increased in length from 280 to 680 millimeters, the volume of fish consumed increased and exceeded the volume of invertebrates when the burbot reached a length of approximately 390 millimeters (Figure 2). The number of stomachs containing fish surpassed those containing invertebrates when burbot reached a length of approximately 450 millimeters. Thus between the third and fifth year, fish become the most important food. As the burbot increase in size they do not appear to eat greater numbers of fish but to take larger fish. A more detailed consideration of variations in food with increase in length is given in the annotated list of food items.

SEASONAL VARIATION IN VOLUME OF FOOD

The average volume of food found in the stomachs from month to month has been calculated, but the resulting analysis is not necessarily a true or complete picture of feeding throughout the year since the rates of digestion at different seasons are not known. In June, 1946, the average volume of food for burbot of all sizes captured was 10.6 milliliters. From July to October inclusive the average volume of food per stomach was never greater than 4.2 milliliters nor less than 3.3 milliliters. The average volume in November, December, March, April, and May was 15.3, 27.7, 39.1, 43.5, and 35.0 milliliters, respectively. Unfavorable conditions during January and February prevented the collection of data at this time. However, it is probable that a large amount of food would be found in the stomachs during this winter period since the number of empty stomachs was inversely related to the amount of food consumed. In July, August, September, and October 40 to 50 percent of the stomachs of burbot captured were empty while during December only about 2 percent of the stomachs examined were empty. A minimum volume of fish with a maximum volume of invertebrates was found in the stomach during the autumn while a maximum volume of fish and a minimum volume of invertebrates was found in the late winter and early spring.

VARIATIONS IN FOOD RELATED TO METHOD OF CAPTURE

There were indications that the results obtained from stomach analyses of burbot captured in pound nets were not comparable with those in gill nets (Table 4). In fish from pound nets, fish items predominated

TABLE 4.—*Variation in quantity of food of burbot caught in gill nets and pound nets—percentage of total shown in parentheses.*

Item	Pound nets	Gill nets
Total number of stomachs	836	4,273
Number empty stomachs	239 (28.6)	1,628 (38.1)
Number stomachs containing food	597 (71.4)	2,645 (61.9)
Number stomachs containing fish	571 (95.6)	1,394 (52.7)
Number stomachs containing invertebrates	122 (20.4)	1,801 (68.2)
Total volume food (milliliters)	15,287	39,805
Volume of fish consumed	15,092 (98.5)	33,964 (85.3)
Volume of invertebrates consumed	209 (1.5)	5,841 (14.7)

in both volume and the number of stomachs containing food. The same result was found in gill-net data but to a lesser degree. On the other hand, the importance of invertebrate food seemed to be considerably less in fish taken from pound nets than in those captured by gill nets. It therefore appears that burbot, while they were impounded with other fish, fed more extensively on fish than they would have under natural conditions.

INCIDENCE OF FISH IN DIETS

Dorosoma cepedianum—Gizzard shad. Occasional; in the stomachs of burbot from the Erieau locality during December, March, and April; from Port Dover during the month of November.

Osmerus mordax—American smelt. Occasional; found in specimens captured in Port Dover locality from July to September, 1946.

Notropis sp.—The shiners. Occasional; occurred in specimens captured in gill nets in December; often large numbers were found in a single stomach; *N. atherinoides* and *N. hudsonius* were both found.

Percopsis omiscomaycus—Troutperch. Common; present in specimens from all parts of the lake sampled; appeared in fewer numbers during November and December; consumed by fish from 300 to 620 millimeters, especially burbot under 460 millimeters in length.

Lepibema chrysops—White bass. Common; observations indicated that white bass were eaten mostly in March and April, and also in greater quantities by those burbot caught in the west part of the central area of the lake; mainly consumed by burbot over 450 millimeters; over 60 percent of the white bass found in stomachs were of marketable size; this fish is caught mainly in the spring.

Perca flavescens—Yellow perch. Very common; found in stomachs of burbot captured in all parts of the lake sampled, especially the central portion; indications point to perch being used considerably during the fall and to a greater extent in the spring; consumed by all sizes over 300 millimeters long and in appreciable quantities by those over 450 millimeters; approximately 17 percent of the perch consumed were marketable size.

Stizostedion vitreum—Pikeperch. Very common; found in specimens captured in all parts of the lake sampled, and particularly in the deep hole region of the lake; seasonal variation showed that a greater part of the burbot's food was pikeperch during the spring and early summer; practically all fish consumed were below marketable size; reports of fishermen and results of experimental gill nets indicate an abundance of this fish in the lake during the course of this study.

Percina caprodes—Logperch. Very common; appeared in burbot stomachs in greatest numbers in the spring of the year from Erieau and Port Stanley; also recorded in specimens from Port Dover, mainly in the autumn.

Aplodinotus grunniens—Freshwater drum. Fairly common; most abundant in March from specimens taken near Erieau; in stomachs from all parts of the lake sampled but a major item for the food of burbot caught in the west end of the central portion; drum are reported by fishermen to be more abundant in western Lake Erie; consumed by burbot from 340 to 620 millimeters; 1- and 2-year-old drum were most commonly found.

Cottus sp.—Fairly common; recorded in specimens from 280 to 600 millimeters long from Port Dover, Port Stanley, and Erieau; fewer appeared during November and December; *Cottus bairdii* were more often identified than *Cottus cognatus*; the former from both ends of the lake while the latter from Port Dover in October.

INCIDENCE OF INVERTEBRATE AND MISCELLANEOUS ITEMS

Miscellaneous Items.—During July, 13 stomachs contained fish eggs in small numbers. At this time, they appeared to be chiefly perch spawn. Burbot captured over the cisco beds in December contained great quantities of eggs; for example the 12 fish of one length class (420 millimeters) contained an average of 7,500 eggs. Fish guts were occasionally found in burbot stomachs. These items were fish entrails thrown overboard by fishermen and picked up by burbot. Generally, a stomach was gorged with fish guts when found.

One unidentified coregonid, one *Bolesoma nigrum,* one *Micropterus dolomieu,* one *Ambloplites rupestris,* one *Lota lota maculosa* were found in burbot stomachs.

Gammarus sp.—Very common; most abundant during the fall and spring from the central portion of the lake.

Asellus sp.—Very common; mainly found in stomachs of burbot collected from the central region of the lake and especially the Erieau locality during the month of November.

Mysis relicta.—Very common; appeared most abundantly during September and October from fish collected in the locality of the deep hole.

Crayfish.—Occasional; in May one offshore collection west of Port Stanley showed that 73 stomachs contained an average of over 30 crayfish per stomach.

Hexagenia (Mayflies).—Usually rare but one offshore collection in May, near Port Stanley, yielded 37 burbot stomachs containing approximately 440 mayflies.

Trichoptera (Caddisflies). — Occurred in more stomachs throughout the year than did any other insect.

Chironomidae (Midges). — Ranked as the third important insect in regard to frequency of occurrence in all stomachs.

Tipulidae (Craneflies).—Occurred in burbot stomachs from July to October from Port Dover; more frequently found in this locality than the midges. All other insects seldom occurred more than once in any of the stomachs.

Mollusca.—Occurred incidentally, never in appreciable numbers.

Sphaeriidae.—Species of Pisidium were: *P. abidtum, P. variabile, P. walkerii, P. idahoense;* occurred more frequently than did the snails. Gastropoda occurred more frequently from burbot taken in the shallow waters than those in the region of the deep hole. *Valvata* sp. Most frequent snail in the stomachs of burbot taken in the central portion of the lake; both *V. sincera* and *V. tricarinata* were found, the former more frequently. *Amnicola limosa.* A less frequently occurring snail that occurred in the stomachs of burbot captured in the central portion. *Lymnea.* A single occurrence from the Erieau locality. *Pleuroceratidae.* Seldom occurred.

ACKNOWLEDGMENT

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FOOD OF YOUNG PIKE, *ESOX LUCIUS* L., AND ASSOCIATED FISHES IN PETERSON'S DITCHES, HOUGHTON LAKE, MICHIGAN[1]

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ABSTRACT

Stomach contents of 551 young pike (11-152 millimeters in length), 345 small yellow perch, and 431 other fish representing 18 species were examined. All specimens were collected from an area widely used by spawning pike from Houghton Lake, Michigan. Organisms utilized for food by young pike included Entomostraca, insects (chiefly Chironomidae), tadpoles, minnows, darters, and other pike. As pike increased in size they passed through a definite feeding succession of Entomostraca to insects to vertebrates (chiefly fish). Cannibalism occurred, as shown by the fact that 13.3 percent of 354 pike 21 millimeters or more in total length had eaten other pike. Smallest pike found to be cannibals were 21 millimeters long. Competition between young pike and most other species of fish for invertebrate food was evident. The yellow perch was the most important fish predator of young pike. Competition for food, predation, and cannibalism undoubtedly were important factors in the high mortality of young pike in their first few weeks of life.

INTRODUCTION

In the past, most of the investigation of food habits of pike *(Esox lucius)* has been directed toward fish of comparatively large size with little attention being given to young individuals. The present report of the food habits of small pike and fishes associated with them covers one phase of the detailed life history study of pike conducted by the junior author at Houghton Lake, Roscommon County, Michigan, in 1939, 1940, and 1942. Field data for this report were collected during the spring and summer of 1939 and 1940 from the drainage ditches which enter Houghton Lake in the immediate vicinity of Peterson's Resort and which served as a spawning ground for adult pike and a rearing ground for the young. A description of these ditches, which drain surrounding marshes, has been given previously (Carbine, 1942). A count of adult pike migrating from the lake into the ditches was

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[1] Contribution from the Michigan Institute for Fisheries Research.

made in 1939, 1940, and 1942. Accurate counts of young pike migrating from the ditches into the lake were also obtained during the first 2 years. In 1942, an estimate of the number of migrating young was made. These data (Carbine, 1944) are summarized as follows:

	1939	1940	1942
Number of spawning females......	125	65	56
Number of spawning males.......	280	81	70
Number of migrating young.......	7,239	1,495	8,000

Mortality of eggs and young pike on the spawning grounds was calculated to be 99.82, 99.93, and 99.56 percent for 1939, 1940, and 1942, respectively (Carbine, 1944). Although fewer eggs were deposited in the marshes in each succeeding year, observations indicated that large numbers of fry survived through hatching and the period of yolk absorption each year and that the survivors appeared to be as numerous in 1940 as in corresponding periods in 1939 and 1942. In each year the number of young observed dwindled before most of them had reached a length of 1 inch.

In each year pike fry began to migrate from the marshes and ditches into Houghton Lake when they had attained a length of about 20 millimeters, and a large percentage of the total number of migrants entered the lake within 6 weeks after hatching began. Some individuals remained in the ditches until late summer, when most of the former spawning area dried up. Along with the spawning pike, small yellow perch *(Perca flavescens)* and several other species of fish 2 to 4 inches in length, moved from the lake into the ditches and were present in the spawning area during the ensuing months. In the spring of 1939, these fish were allowed to enter the ditches for only 1 day and further entry was prevented by a weir. In 1940 and 1942 they were not hindered from entering the ditches during the entire period of investigation. This association of young pike with various other species is a natural condition which unquestionably had an important bearing on the survival and growth of the pike.

METHODS OF COLLECTION AND STOMACH ANALYSIS

Young pike, yellow perch, and 18 other species of fish were collected with seines, dip nets, minnow traps, and weirs. From May 6 to July 3, 1939, 33 collections of pike and 11 collections of other fish were secured. In 1940, 17 collections of pike and 13 collections of other fishes were obtained from May 6 to June 13. Species of fish other than pike collected in sufficient numbers for stomach analyses are listed in Table 1.

The total length of each fish was recorded to the nearest millimeter, and the stomach was removed and opened under a low-power, widefield binocular microscope. Food organisms were removed, identified, counted, and the volume of each kind of organism either measured by water displacement or estimated. In summarizing the data obtained, frequency of occurrence and percentage of total food volume were considered in determining the importance of various food organisms in the diets of the fishes concerned. Only those stomachs containing food were used in the calculation of the percentages of various food items in the stomachs. Qualitative examination of stomachs and intestines of pike and other fishes revealed that the contents of the two regions were very similar in most individuals. Therefore stomach contents alone were itemized in the food study.

Pike smaller than 40 millimeters in length were placed in 5-millimeter size groups, and larger individuals in 10- and 20-millimeter size groups. Analyses of food were made on a basis of these divisions. An individual food analysis was made for each collection of perch but other species were grouped together without regard for size or collection date.

SIZE AT WHICH PIKE BEGIN TO FEED

Fourteen fry 10 to 11 millimeters in length, collected in 1940, still carried a considerable amount of yolk and had taken no food. Two individuals 11 millimeters in length obtained in 1939 showed no trace of the yolk sac and had been actively feeding. One contained a *Chydorus* and a *Simocephalus;* the other, two *Chydorus,* two *Canthocamptus,* and one ostracod. Ten individuals 12 millimeters in length secured in 1939 showed no trace of yolk remaining and all had eaten several kinds of cladocerans, copepods, and ostracods. The number of food organisms per stomach ranged from 2 to 24. In 1940, two of four pike 12 millimeters in length still showed traces of yolk and had taken no food. The

TABLE 1.—*Species of fish collected for stomach analyses found associated with young pike.*[1]

Species		Year collected	
Common name	Scientific name	1939	1940
Yellow perch	*Perca flavescens* (Mitchill)	x	x
Bluegill	*Lepomis m. macrochirus* (Rafinesque)	x	......
Rock bass	*Ambloplites r. rupestris* (Rafinesque)	x	......
Pumpkinseed	*Lepomis gibbosus* (Linnaeus)	x	......
Brook stickleback	*Eucalia inconstans* (Kirtland)	x	x
Central mudminnow	*Umbra limi* (Kirtland)	x	x
Blackside darter	*Hadropterus maculatus* (Girard)	x	......
Iowa darter	*Poecilichthys exilis* (Girard)	x	x
Northern creek chub	*Semotilus a. atromaculatus* (Mitchill)	x	x
Northern redbelly dace	*Chrosomus eos* (Cope)	x	x
Western golden shiner	*Notemigonus crysoleucas auratus* (Rafinesque)	x	x
Brassy minnow	*Hybognathus hankinsoni* (Hubbs)	x	......
Bluntnose minnow	*Hyborhynchus notatus* (Rafinesque)	x	x
Northern common shiner	*Notropis cornutus frontalis* (Agassiz)	x	......
Blackchin shiner	*Notropis heterodon* (Cope)	x	......
Northern blacknose shiner	*Notropis h. heterolepis* (Eigenmann and Eigenmann)	x	x
Great Lakes spottail shiner	*Notropis h. hudsonius* (Clinton)	x	x
Rosyface shiner	*Notropis rubellus* (Agassiz)	x	x
Northern mimic shiner	*Notropis v. volucellus* (Cope)	x	x

[1] Identified by Walter R. Crowe.

TABLE 2.—*Occurrence of major groups of food organisms in stomachs of young pike collected in 1939.*

Size group (millimeters)	Number of pike	Entomostraca		Insects		Vertebrates		Average number of organisms per stomach
		Percentage of stomachs containing organism	Percentage of total food volume	Percentage of stomachs containing organism	Percentage of total food volume	Percentage of stomachs containing organism	Percentage of total food volume	
11—15	56	100.0	65.9	16.1	34.1	0.0	0.0	9.3
16—20	59	98.3	58.8	28.8	41.2	0.0	0.0	12.8
21—25	56	80.4	21.6	51.8	38.0	25.0	40.4	26.3
26—30	34	73.5	5.0	58.8	31.2	32.3	63.8	7.5
31—35	25	60.0	2.5	72.0	47.0	24.0	50.0	7.8
36—40	16	31.2	8.7	87.5	41.7	18.7	49.6	8.8
41—50	9	44.4	0.7	55.5	13.9	44.4	85.4	3.9
51—60	24	25.0	0.3	50.0	11.4	45.8	88.3	3.8
61—80	12	0.0	0.0	16.6	0.4	66.7	97.7	0.7
81—100	7	0.0	0.0	0.0	0.0	100.0	100.0	0.6
101—152	20	0.0	0.0	15.0	Trace	85.0	99.6	1.4

other two contained *Simocephalus* and *Chydorus* and had completely absorbed the yolk sac. Eight fry 13 millimeters in length had eaten quantities of copepods, cladocerans, and ostracods. One specimen contained 64 entomostracans, and a chironomid larva and pupa. Food organisms in the stomachs of these eight fry varied in number from 7 to 66. It appears that pike fry begin active feeding when they reach a length of 11 to 12 millimeters and may start even before the yolk sac is completely absorbed.

FOOD OF YOUNG PIKE

A total of 651 specimens was examined, of which 318 obtained in 1939 and 233 secured in 1940 contained food material. Data obtained from stomach examination substantiated observations of the voracious nature of the fry. Feeding apparently occurred in at least two habitats for not only were free-swimming organisms eaten, but judging from the number of chironomid larvae and ostracods in the diet, a considerable amount of foraging occurred on or near the bottom. Tadpoles and minnows were eaten as soon as the pike were large enough to handle them. Cannibalism began at a length of 21 millimeters and was especially frequent among the pike collected in 1939.

Food habits of young pike change as they increase in size and three feeding stages are evident during the period of change (Table 2). The first, extending from the time the fry begin to feed until they reach a length of about 25 millimeters, is one of feeding mainly upon entomostracans. In the second stage, which occurs during the period of growth from 26 to 50 millimeters in length, the food is mostly immature

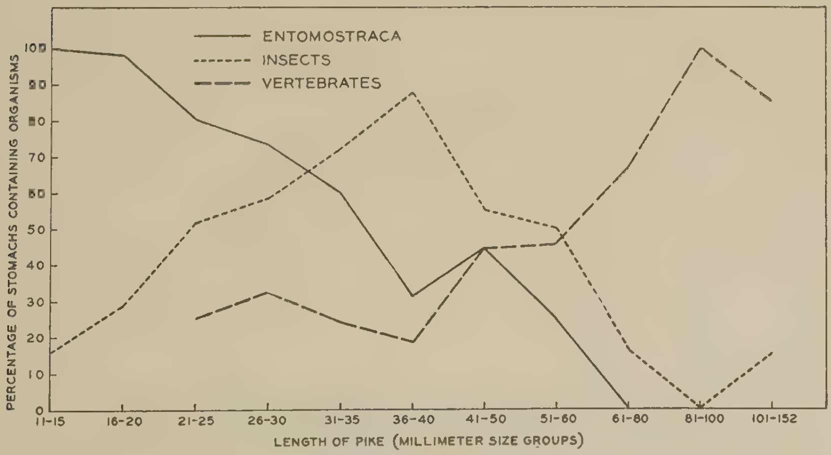

FIGURE 1.—Frequency of occurrence of major groups of food organisms in stomachs of pike collected in 1939.

TABLE 3.—*Occurrence of major groups of food organisms in stomachs of young pike collected in 1940.*

Size group (millimeters)	Number of pike	Entomostraca		Insects		Vertebrates		Average number of organisms per stomach
		Percentage of stomachs containing organism	Percentage of total food volume	Percentage of stomachs containing organism	Percentage of total food volume	Percentage of stomachs containing organism	Percentage of total food volume	
11—15	21	100.0	68.2	33.3	31.8	0.0	0.0	32.0
16—20	59	100.0	75.7	28.8	23.8	0.0	0.0	54.3
21—25	35	100.0	62.7	60.0	37.3	0.0	0.0	78.7
26—30	24	91.7	15.6	83.3	75.6	4.2	8.8	29.1
31—35	15	86.7	7.4	80.0	41.9	13.3	47.4	13.0
36—40	17	64.7	9.0	64.7	65.8	5.8	22.9	9.0
41—50	39	53.8	5.0	56.4	26.3	7.7	65.1	7.3
51—60	10	50.0	1.5	60.0	48.0	30.0	50.5	2.4
61—80	2	0.0	0.0	50.0	10.7	50.0	89.3	1.5
81—100	4	0.0	0.0	25.0	2.9	100.0	97.1	1.2
101—136	7	0.0	0.0	0.0	0.0	100.0	100.0	1.0

aquatic insects. In the third stage, characteristic of pike larger than 50 millimeters, the diet is composed almost entirely of fish and other vertebrates. There is a great deal of overlapping in the feeding habits of young pike of all sizes, but in general the feeding sequence, as fish increase in size, is Entomostraca to insects to fish. This sequence has been found to occur during the development of smallmouth black bass, largemouth black bass, yellow perch, white bass, and other predaceous fishes (Adams and Hankinson, 1928; DeRyke, 1922; Ewers, 1934; Forbes, 1888; Pearse, 1918; Surber, 1941; Tester, 1932; and others).

Close agreement in the relative quantities of major groups of food organisms entering into the pike diet in 1939 and 1940 is apparent in Tables 2 and 3. The same food trends are also evident for both years. This feeding succession is clearly shown in Figures 1 and 2.

Crustacean food.—Food first taken by young pike consisted primarily of cladocerans, of which the smaller forms, chiefly *Chydorus, Pleuroxus,* and *Scapholeberis,* predominated. Larger forms such as *Simocephalus* and *Eurycercus* were eaten more frequently by fish in the 21- to 25-millimeter group. *Daphnia* and *Bosmina* were eaten infrequently, and *Polyphemus* appeared only in stomachs collected on June 5 and 8, 1940. Copepods were a major food item for pike up to 26 millimeters long but rapidly diminished in importance as fish grew larger. *Cyclops* was most abundant in stomachs. *Canthocamptus, Diaptomus,* and *Osphranticum* occurred less frequently. Ostracods were eaten consistently, although in small quantities, by fish up to 70 millimeters in length. Stomachs of 77.4 percent of the pike under 21 millimeters and 39.1 percent of all those under 60 millimeters obtained in 1939 contained Entomostraca exclusively. In 1940, 68.7 percent of fish under 21 millimeters and 43.4 percent of those under 60 millimeters had eaten only Entomostraca.

Insect food.—Although insects formed an appreciable percentage of the total volume of food of pike from 11 to 70 millimeters in length, they were of greatest importance in the diet of fish between 26 and 50 millimeters long. Insect food consisted entirely of aquatic larvae, pupae, and nymphs. Midge larvae and pupae, principally chironomids, formed the bulk of the insect food. Beetle larvae, mayfly nymphs *(Blasturus* and *Ephemerella),* and dragonfly nymphs were consumed in small quantities.

Vertebrate food.—Tadpoles, which appeared in the ditches in late May, were eaten by all sizes of pike from 26 to 152 millimeters but were consumed much more frequently by larger specimens. These amphibians formed 7.6, 13.3, and 37.4 percent of the total food volume of all pike collected in both years in the 21 to 40-, 41 to 80-, and 81 to 152-millimeter size groups, respectively. Fish, other than pike, did not appear in the stomach contents of pike smaller than 51 millimeters but formed an increasingly large part of the food of larger specimens. Northern mimic shiner, rosyface shiner, bluntnose minnow, golden

TABLE 4.—*Comparison between the lengths of cannibal pike and pike found in their stomachs. Fish collected in 1939.*

Size group (millimeters)	Number of pike stomachs examined	Number of stomachs containing pike	Cannibal pike (Total length-millimeters)			Prey (pike) (Total length-millimeters)		
			Minimum	Maximum	Average	Minimum	Maximum	Average
21—25	56	14	21	25	23.3	11	17	14.1
26—30	34	11	26	30	27.8	12	20	15.1
31—35	25	5	31	35	32.4	13	18	15.6
36—40	16	2	36	37	36.5	15	20	17.5
41—50	9	0	....	....	....	....	....	....
51—60	24	4	52	60	55.6	8	30	13.2
61—80	12	2	74	78	76.0	44	45	44.5
81—100	7	1	94	94	94.0	20	20	20.0
101—152	20	1	102	102	102.0	....	....	....

shiner, creek chub, brook stickleback, and brassy minnow were identified in the stomachs.

Other pike formed the chief vertebrate constituent of the diet of fish 21 to 80 millimeters in length captured in 1939. Fourteen (25 percent) members of the 21- to 25-millimeter size group and 11 (32.2 percent) of those in the 26- to 30-millimeter group collected in 1939 had eaten other pike. Judging from the stomach contents, cannibalism was much more extensive in 1939 than in 1940. In the latter year only 7 stomachs of 233 examined contained other pike. Table 4 shows the extent of cannibalism in 1939 and the relative length of cannibal pike and those which were eaten. Minimum difference in length between predator (23 millimeters) and prey (16 millimeters) was 7 millimeters. The fact that young pike eat others of nearly two-thirds their own length is ample demonstration of their voracity and suggests that cannibalism is an important factor in reducing their own population.

Other food.—Few organisms, other than those previously discussed, appeared in the stomachs. Snails occurred in four specimens and Hydracarina in two individuals. Plant debris was found in a few stomachs of fish over 80 millimeters in length but was undoubtedly taken while capturing animal food.

COMPARISON OF FOOD USE WITH AVAILABILITY

In order to compare the plankton organisms found in the habitat with those found in the pike stomachs, four plankton samples (20 to 50 gallons of water strained through a plankton net for each sample) were obtained at the same time and place that collections of pike were made.

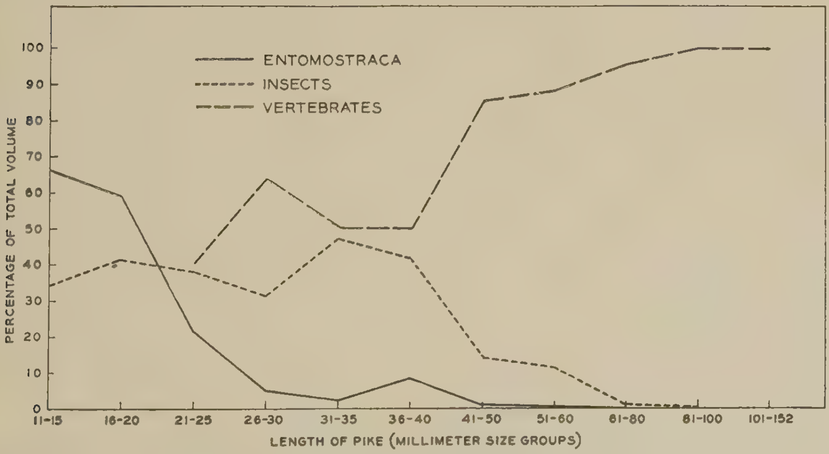

FIGURE 2.—Percentage of total food volume composed of major groups of food organisms in stomachs of pike collected in 1939.

TABLE 5.—*Comparison of Entomostraca eaten by pike with Entomostraca found in plankton samples—1940.*[1]

			Stomach contents (Entomostraca)			Plankton sample (Entomostraca)		
Date of collection	Number of stomachs with contents	Size range of pike (millimeters)	Organism	Total number of organisms in stomachs	Percentage of total number of organisms in stomachs	Organism	Total number of organisms in sample	Percentage of total number of organisms in sample
May 10	14	13—16	*Chydorus*	523	87.6	*Chydorus*	3,540	81.1
			Cyclops	35	5.9	*Cyclops*	255	5.8
			Simocephalus	22	3.7	*Bosmina*	180	4.1
			Canthocamptus	6	1.0	Nauplii	135	3.1
			Ostracoda	5	0.8	Ostracoda	120	2.8
			Scapholeberis	5	0.8	*Simocephalus*	60	1.4
			Bosmina	1	0.2	*Scapholeberis*	45	1.0
						Canthocamptus	30	0.7
May 11	8	13—14	*Chydorus*	121	69.5	*Cyclops*	1,243	44.7
			Pleuroxus	21	12.1	Nauplii	990	35.6
			Canthocamptus	14	8.1	*Chydorus*	370	13.3
			Ostracoda	12	6.9	*Canthocamptus*	104	3.7
			Cyclops	6	3.4	Ostracoda	44	1.6
						Pleuroxus	30	1.1
May 25	23	20—33	*Chydorus*	648	47.5	*Chydorus*	182	32.6
			Cyclops	373	27.4	*Cyclops*	109	19.5
			Pleuroxus	183	13.5	*Pleuroxus*	85	15.2
			Ostracoda	99	7.4	Ostracoda	61	10.9
			Simocephalus	40	2.9	*Canthocamptus*	61	10.9
			Diaptomus	10	0.7	Nauplii	36	6.5
			Canthocamptus	9	0.6	*Scapholeberis*	12	2.2
			Scapholeberis	1	Trace	*Bosmina*	12	2.2
May 28	8	25—29	*Simocephalus*	27	45.8	*Chydorus*	160	46.8
			Pleuroxus	12	20.2	Ostracoda	44	12.9
			Ostracoda	6	10.2	*Cyclops*	44	12.9
			Chydorus	4	6.8	*Pleuroxus*	19	5.4
			Cyclops	4	6.8	*Simocephalus*	15	4.4
			Osphranticum	3	5.1	*Canthocamptus*	15	4.4
			Eurycercus	1	1.7	*Bosmina*	15	4.4
			Scapholeberis	1	1.7	*Polyphemus*	15	4.4
			Diaptomus	1	1.7	Nauplii	15	4.4

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[1] Plankton samples counted and organisms identified by L. Edward Perry.

Comparison of the relative abundance of various genera of Entomostraca in the plankton samples with those consumed by young pike shows that in two instances many of the microcrustaceans were eaten in direct proportion to their abundance (Table 5). In the other two cases much less agreement in relative abundance is evident. It is possible that on those dates on which relative numbers of organisms eaten and those in plankton samples showed little correspondence, the small number of stomachs collected did not give a representative picture of the feeding habits of the pike population at that time. It should be noted that nauplii, generally abundant in the plankton samples, were not found in the pike stomachs. Although the data are not conclusive, it appears that young pike are not selective in their feeding but tend to eat those organisms which are most abundant providing they are large enough to be of interest. Since Entomostraca are so important in the diet of pike in their first few weeks of life, it is probable that the abundance or scarcity of these organisms would be an important factor in the initial survival of the fry.

EFFECT OF FOOD HABITS ON GROWTH RATE

Growth rate of pike (Carbine, 1942) showed a marked increase after the average length of fish had reached 44.2 millimeters in 1939 and 39.3 millimeters in 1940. Vertebrates and large insects formed the bulk of the food of fish in the 41- to 50-millimeter group in both years. The increased daily growth rate in June coincided with the appearance of larger food items (particularly fish) in the diet of pike collected at that time. Since increased growth rate occurred at the same time as the transition from invertebrate to vertebrate food, it appears that an accelerated growth rate is associated with the change to a vertebrate diet.

COMPETITION BETWEEN YOUNG PIKE AND OTHER FISH

That competition for various food organisms existed between the pike and other species of fish present in the ditches was clearly shown by analysis of the stomach contents of yellow perch (Tables 6 and 7) and other species of fish (unpublished). The degree of competition is evident in the relative abundance of various types of food in the stomachs of different species and different size groups of pike (Table 8). What bearing competition for food had on survival and growth of young pike cannot be determined since no information is available concerning the adequacy or inadequacy of the natural food supplies available. However, competition necessarily reduced the food supply and may have been a factor in the mortality of young pike.

Crustacean food.—Most species of fish ate entomostracans to some extent and competed with pike up to 40 millimeters in length for this food source. The brook stickleback, golden shiner, blacknose minnow, spottail shiner, and mimic shiner consumed considerable quantities of

Table 6.—*Summary of stomach contents of 95 yellow perch collected in 1939. Number of stomachs with contents 78, without 17. (L = larvae, P = pupae, N = nymph)*

Organism	Number of stomachs containing organism	Percentage of stomachs containing organism	Most organisms in any stomach	Average number of organisms in stomachs containing them	Percentage of total number of organisms	Percentage of total volume
Entomostraca	16	20.5	461	66.6	79.2	6.0
Cladocera	11	14.1	62	18.4	15.1	2.3
Copepoda	9	11.5	450	95.8	64.1	3.5
Malacostraca						
Amphipoda	3	3.8	3	1.7	0.4	Trace
Insecta	69	88.5	21	3.7	19.6	69.4
Diptera	20	25.7	18	6.3	9.4	13.8
Chironomidae (L)	8	10.2	3	1.5	0.9	1.0
Chironomidae (P)	13	16.6	18	7.9	7.6	10.5
Culicidae (L)	6	7.7	5	2.0	0.9	2.3
Ephemeroptera (N)	58	74.3	6	2.4	10.2	55.6
Coleoptera (L)	1	1.3	1	1.0	Trace	Trace
Vertebrates						
Pike	8	10.2	3	1.2	0.8	24.6

Average number of organisms per stomach 17.2.
Average volume per stomach in cubic centimeters 0.027.

TABLE 7.—*Summary of stomach contents of 547 yellow perch collected in 1940. Number of stomachs with contents 267, without 280. (L = larvae, P = pupae, N = nymph, A = adult.)*

Organism	Number of stomachs containing organism	Percentage of stomachs containing organism	Most organisms in any stomach	Average number of organisms in stomachs containing them	Percentage of total number of organisms	Percentage of total volume
Entomostraca	72	26.9	....	....	55.1	0.9
Cladocera	48	17.9	48	8.8	11.5	0.5
Copepoda	45	16.8	391	35.4	43.6	0.4
Ostracoda	1	0.4	2	2.0	Trace	Trace
Malacostraca						
Amphipoda	2	0.8	6	3.5	0.2	0.1
Insecta	201	75.3	83	7.2	42.7	29.1
Diptera	141	52.8	49	9.1	34.9	10.8
Chironomidae (L)	132	49.4	47	5.8	20.9	5.8
Chironomidae (P)	111	41.6	33	4.9	13.9	3.2
Culicidae (L)	3	1.1	1	1.0	Trace	0.1
Anthomyidae (L)	1	0.4	5	5.0	0.1	1.7
Odonata						
Anisoptera (N)	9	3.3	22	4.3	1.1	0.5
Zygoptera (N)	7	2.8	19	5.8	1.1	0.8
Ephemeroptera (N)	12	4.5	13	2.7	0.9	0.6
Ephemeroptera (A)	8	3.0	8	3.6	0.8	9.3
Trichoptera (L)	32	12.0	12	2.3	2.0	6.5
Coleoptera (L)	27	10.1	16	2.8	1.9	0.6
Vertebrates	67	25.1	3	1.1	2.0	69.8
Amphibia (Tadpole)	1	0.4	1	1.0	Trace	0.7
Fish	66	24.7	3	1.1	2.0	69.1
Pike	63	23.6	3	1.1	2.0	68.9
Cyprinidae	1	0.4	1	1.0	Trace	0.1
Fish remains	2	0.8	1	1.0	Trace	0.1

Average number of organisms per stomach 13.7.
Average volume per stomach in cubic centimeters 0.044.

TABLE 8.—*Comparison of food eaten by various size groups of pike with diet of other species of fish taken at the same time. Data collected in 1939 and 1940 combined.*

Species	Stomachs with contents	Entomostraca		Insects		Pike		Other vertebrates (Fish and tadpoles)		Algae and plant debris	
		Per-centage of stomachs containing organisms	Per-centage of total food volume	Per-centage of stomachs containing organisms	Per-centage of total food volume	Per-centage of stomachs containing organisms	Per-centage of total food volume	Per-centage of stomachs containing organisms	Per-centage of total food volume	Per-centage of stomachs containing material	Per-centage of total food volume
Pike (11-20 millimeters)	195	99.5	67.3	25.6	32.7	....	....	....	....	....	....
Pike (21-40 millimeters)	222	77.5	15.7	65.3	47.3	14.9	25.3	2.3	10.0	0.5	Trace
Pike (41-80 millimeters)	94	38.3	1.5	50.0	20.0	9.6	23.5	17.3	54.2	12.8	0.8
Pike (81-152 millimeters)	38	....	....	10.6	Trace	13.2	6.5	73.7	91.5	10.6	2.0
Yellow perch	345	25.5	1.7	78.3	35.4	20.6	62.0	1.2	0.7	....	....
Pumpkinseed	13	23.1	Trace	92.3	96.8	....	....	....	....	....	....
Bluegill	1	....	....	100.0	100.0	....	....	....	....	....	....
Rock bass	2	....	....	100.0	100.0	....	....	....	....	....	....
Brook stickleback	10	90.0	32.4	70.0	67.6	....	....	....	....	....	....
Mudminnow	19	31.6	4.5	68.4	59.1	....	....	5.3	4.5	31.6	Trace
Blackside darter	24	8.4	Trace	100.0	100.0	....	....	....	....	....	....
Iowa darter	46	43.5	3.8	93.5	96.2	....	....	....	....	4.3	Trace
Creek chub	11	....	....	63.6	7.9	9.1	1.4	18.2	76.2	9.1	14.4
Redbelly dace	36	30.6	Trace	55.6	21.2	....	....	....	....	38.9	78.8
Brassy minnow	20	....	....	....	....	....	....	....	....	100.0	100.0
Golden shiner	35	71.4	57.7	20.0	11.5	....	....	....	....	40.0	30.8
Bluntnose minnow	48	31.2	Trace	16.7	2.2	....	....	....	....	83.3	97.0
Common shiner	18	....	....	94.4	83.3	....	....	....	....	5.5	16.7
Blackchin shiner	20	20.0	4.4	80.0	81.5	5.0	14.1	....	....	5.0	Trace
Blacknose shiner	34	85.3	48.0	41.2	36.0	....	....	....	....	20.6	16.0
Spottail shiner	25	48.0	46.2	40.0	30.7	....	....	....	....	24.0	23.1
Rosyface shiner	14	14.3	4.7	100.0	95.3	....	....	....	....	....	....
Mimic shiner	55	47.3	16.0	38.2	36.9	3.6	14.4	....	....	43.6	30.4

entomostracans. These organisms occurred in 47.3 to 90.0 percent of the stomachs of these fish and formed from 16.0 to 57.7 percent of the total food volume.

Insect food.—Competition for insects between young pike and other fish associated with them was pronounced. Larvae and pupae, particularly those of Chironomidae, were consumed by all sizes of pike, yellow perch, and most other fish. Those fish which fed on chironomids extensively and thereby competed directly with pike, particularly those in the 21- to 50-millimeter size group, were: yellow perch, brook stickleback, mudminnow, Iowa darter, creek chub, golden shiner, redbelly dace, common shiner, blackchin shiner, blacknose shiner, spottail shiner, rosyface shiner, and mimic shiner. Effect of competition for insects, particularly chironomids, on the survival and growth of young pike cannot be accurately evaluated. Nevertheless, it is not improbable that the total competition for the insect food supply may have affected pike adversely during the insect-feeding stage.

Vertebrate food.—Very little competition existed between the pike and other fish for tadpoles and minnows. Yellow perch, mudminnows, and creek chubs consumed minnows to a limited extent and ate few tadpoles. If it is considered that young pike themselves are food for other pike, then perch would be a competitor of some importance for they decreased the number of pike fry available to the cannibals in the population.

PREDATORS OF YOUNG PIKE

In view of the small number of young pike that survived the first few weeks after hatching, there is no doubt that predation played an important role in the reduction of the population (Carbine, 1942, 1944). Perch and other fish present in the ditches consumed many young and the pike themselves were responsible in large measure for the reduction in numbers through cannibalism. Yellow perch (61 to 120 millimeters in total length) present in both years but more abundant in 1940 proved to be the most important fish predator. Of the 345 yellow perch stomachs which contained food, 71 (20.6 percent) contained one or more pike, which constituted 62.0 percent of the total volume of stomach contents. Most pike eaten by perch ranged from 12 to 36 millimeters in length (average length about 25 millimeters). The extent to which pike were eaten by perch in both 1939 and 1940 is shown in Table 9. Average length of pike eaten was about one-third of the average length of the perch which ate them and is probably near the maximum size of prey that these fish could eat with ease. By May 27, 1939 and June 8, 1940, the average length of pike was 44.2 and 38.3 millimeters, respectively; this fact suggests that the pike were reaching sufficient size so that perch were no longer able to feed freely upon them, and probably explains why no small pike were found in perch stomachs collected on May 23-24 and 27, 1939, and on June 8, 1940.

TABLE 9.—*Extent to which young pike were eaten by perch in each perch collection of 1939 and 1940.*

Collection date	Number of perch stomachs with contents	Percentage of stomachs containing pike	Percentage of total food volume composed of pike
1939			
May 9	52	7.7	3.0
May 12-16	2	0.0	0.0
May 20	6	66.7	88.2
May 23-24	11	0.0	0.0
May 27	7	0.0	0.0
1940			
May 13	25	8.0	19.2
May 22	5	40.0	94.3
May 27	14	14.4	65.7
May 28	45	22.2	87.5
May 29	15	13.3	51.8
May 30	19	36.8	95.9
May 31	32	25.0	76.1
June 1	31	45.2	87.0
June 2	16	25.0	73.9
June 3	13	30.8	75.0
June 4	7	28.6	83.3
June 5	20	30.0	63.8
June 8	25	0.0	0.0
Total	345	20.6	62.0

Of all other fish collected in 1939 and 1940, only the creek chub, blackchin shiner, and mimic shiner contained pike. It is not improbable, however, that most fishes associated with the pike fry consumed them to some extent. On May 8, 1942, the trap at the fry weir contained 21 pike, 5 pumpkinseeds, and 4 mudminnows. The pumpkinseeds contained a total of 12 pike and the mudminnows a total of 16. This high incidence was no doubt due to the availability of the pike fry in the trap.

Other animals such as birds, dragonfly and damselfly nymphs, beetle larvae, and water bugs (Belostomatidae) were observed to capture and eat young pike.

DISCUSSION AND CONCLUSIONS

It is evident from the data obtained that predation, cannibalism, and competition for available food between young pike and the fish associated with them in the ditches were factors in the high mortality rate of pike fry. The greater abundance of small yellow perch and other fish in the ditches in 1940 than in 1939 probably contributed significantly to the lower production of pike in 1940. Observations on the number of perch and other fish present in 1942 are incomplete; therefore no comparison with other years is possible.

In 1939 pike fry began to migrate from the ditches into Houghton Lake on May 12, 10 days after hatching, at an average length of 19 millimeters, and 85.4 percent of the total migrants moved into the lake in the succeeding 20-day period. In 1940, the first young (average length 23 millimeters) moved to the lake on May 25, 22 days after the first fry were observed in the ditches, and only 24.9 percent of the total run of fish entered the lake in the following 7-day period. The 12-day delay in the beginning of the lakeward migration of fry in 1940 offered greater opportunity for extensive losses in the ditches and marshes through predation, cannibalism, and other causes than in the previous year. Since more young moved downstream from the marshes to the lake on bright days than on cloudy days, an extended period of overcast weather, such as occurred in 1940, would offer more favorable conditions for losses from the causes mentioned above. A reduction in the number of predators in the spawning marshes may not necessarily result in a lessened mortality of young pike because cannibalism, known to be the chief cause of pike mortality in experimental ponds (Carbine, 1945), would still reduce the population to a low level.

Although competition, predation, and cannibalism unquestionably cause the loss of many young pike, other unfavorable conditions such as low water levels and limited spawning areas are no doubt of great significance in the survival of the young on the spawning grounds.

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THE STATUS OF THE FISH FAUNA OF THE LAKE MEAD NATIONAL RECREATIONAL AREA, ARIZONA-NEVADA

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Abstract

The Colorado River flows for nearly 225 miles through the Lake Mead National Recreational Area, Arizona-Nevada. Its character has been controlled and changed as the result of construction of Hoover and Davis Dams. The composition of the fish fauna has changed, also. There are now known from the area 3 native and 11 exotic species. Six additional fishes native to the Colorado River Basin and two other alien forms may occur.

Competition with the exotic species and changes in ecological conditions of the river have apparently brought about decline in the numbers of native fishes. This peculiar fauna, so poorly known at present, should be the object of more scientific investigation and survey before it becomes extinct or its composition is further altered.

Introduced species have increased since the building of Hoover Dam. The largemouth black bass is the most important game species in Lake Mead and the rainbow trout is the leading sport fish in Lake Mohave. It is probably unnecessary to have a closed fishing season because the exotic game fishes are so firmly established. Introduction of additional alien species is not recommended. Further stocking of the largemouth black bass or forage fishes in Lake Mead is discouraged, although continued planting of rainbow trout below Hoover Dam is necessary to meet anglers' demands. Further investigation of the sport fishery in Lake Mead National Recreational Area is desirable.

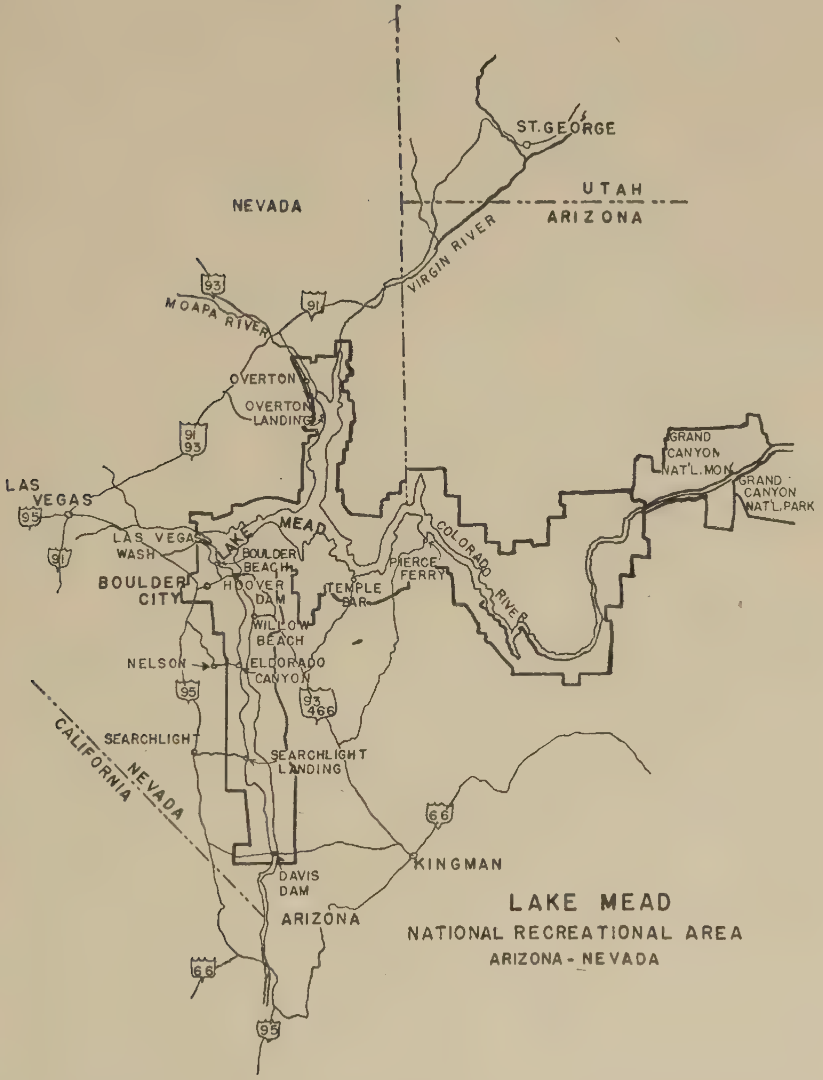
Introduction

This report, in which native and exotic fishes are discussed, is an attempt to reveal the present status of the fish fauna of Lake Mead National Recreational Area, Arizon-Nevada, as a contribution to the existing knowledge of the fish composition of the Colorado River.

Evermann and Rutter (1895), Gilbert and Scofield (1898), Snyder (1915), Dill (1944), and Miller (1946a, b) have already suggested that the indigenous fauna of the Colorado River is not rich in species but is of interest because of its high degree of endemism. The fauna is in urgent need of further research, because many forces are fast exterminating it (Dill, 1944; Miller, 1946a, b).

The fishes of the Lake Mead National Recreational Area consist of 3 native and 11 exotic species representing six families. In addition, six native fishes and two exotic forms are mentioned.

Studies of the fishes of this area by Moffett (1942, 1943) and Eicher (1947) primarily considered management of the introduced game species of Lake Mead and of the Colorado River below Hoover Dam.


ST. GEORGE
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GRAND CANYON NAT'L. MON.
GRAND CANYON NAT'L. PARK
LAS VEGAS
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LAS VEGAS WASH
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LAKE MEAD
BOULDER BEACH
BOULDER CITY
HOOVER DAM
PIERCE FERRY
TEMPLE BAR
COLORADO RIVER
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LAKE MEAD
NATIONAL RECREATIONAL AREA
ARIZONA - NEVADA

FIGURE 1.—The Lake Mead National Recreation Area in Arizona and Nevada.

Description of the Area

Consisting of nearly 3,000 square miles, Lake Mead National Recreational Area, administered by the National Park Service, follows the winding course of the Colorado River from Grand Canyon National Monument in northwestern Arizona to Davis Dam, nearly 200 miles downstream, in southeastern Nevada. This is an arid, semidesert region in which the summers are hot and dry, but the winters are cool and mild (Figure 1).

The main features are the two extensive reservoirs, Lake Mead and Lake Mohave, formed by Hoover and Davis Dams. Originally Lake Mead stretched eastward for 115 navigable miles above Hoover Dam, reaching for 39 miles into the lower end of Grand Canyon. As the result of siltration in the upper portions, the upstream limit of the lake is now only 85 miles from the dam. At its height, following completion of the dam in 1936, the lake had a shoreline of over 500 miles and a depth of 589 feet.

After it enters the recreational area on the east, the Colorado River flows for 69 tempestuous miles through the lower extension of Grand Canyon before it pours into Lake Mead. Grand Wash, which enters the lake below Pierce Ferry, is dry except when occasional cloudbursts send torrents dashing down its course.

The Virgin River and its former tributary, the Moapa (Muddy) River, enter Lake Mead from the north into Virgin Basin. Beyond Boulder Canyon, the lake turns abruptly southward and is joined by the small Las Vegas River emerging from Las Vegas Wash.

From Hoover Dam, the clear, cold water flows into the recently formed Lake Mohave. When filled, this lake will extend almost to the base of Hoover Dam. Unlike Lake Mead it will be narrow, with a maximum width of only 4 miles. Its shoreline will be 200 miles long and its water level is not expected to fluctuate more than 10 feet annually. In the upper reaches, where the water temperature averages 56° F., Lake Mohave will be suitable for trout. Before the water reaches Davis Dam, it will have warmed sufficiently to provide favorable conditions for largemouth black bass and other warm-water game species. At present, however, only trout will be planted.

Native Fishes

Only three native fishes have been collected in the recreational area: the razorback sucker, the Colorado squawfish, and the bonytail.

The waters of the Colorado River in this area, which were originally swift, heavily silt-laden, and subject to rapid changes in turbidity and volume, are now regulated to produce clear, placid waters above and below Hoover Dam. The native fishes are adapted to the rigorous swift-water habitat by a reduction in scale size and by having streamlined bodies (Miller, 1946b).

Following completion of Hoover Dam the native fishes in the lower Colorado River began to decline in numbers accompanied by a simultaneous increase in the exotic species (Dill, 1944). Predation by and competition with the exotic species and changes in the ecological conditions of the river are causal factors in the depletion of the indigenous fishes. The razorback sucker is the one exception. This species appears to be holding its own and reproducing abundantly in Lake Mead.

In addition to the existing man-made structures, 134 projects or units of projects for irrigation, power production, flood and silt control, channel improvement, municipal and other uses are proposed (Anonymous, 1946). It is evident that the native fishes of this and other portions of the Colorado River Basin are destined to become scarce or locally exterminated. It is regrettable that little can be done to save them, for our present knowledge of these species is very incomplete (Dill, 1944; Miller, 1946a, b). Consequently, this fauna should become the object of more intensive research before it has disappeared completely or its composition has been altered further.

In addition to the three native species mentioned above, six others may occur within the area. The humpback chub, *Gila cypha* Miller, a remarkable specialized species, closely related to the bonytail, was described from the Colorado River in Grand Canyon National Park (Miller, 1946b). The flannelmouth sucker, *Catostomus latipinnis* Baird and Girard, is found in Virgin River and farther up the Colorado River (Tanner, 1932, 1936; Miller, 1946b). The occurrence of the western dace, *Rhinichthys osculus* Girard, in Las Vegas Creek, a flood tributary to Lake Mead, was reported by Hubbs and Miller (1948b).

Live bait for Lake Mead anglers is brought from the Santa Clara River, a tributary to the Virgin River, near St. George, Utah. This source of bait fishes has been utilized for several years.

The following fishes were collected from bait tanks at Las Vegas Wash and Boulder Beach docks: flannelmouth sucker; Utah mountain sucker, *Pantosteus delphinus utahensis* (Tanner); western dace; scaled spiny dace, *Lepidomeda vittata* Cope; a sculpin, *Cottus bairdii* Girard; and carp. Representatives of the entire fish fauna of the Santa Clara River (as listed by Tanner, 1932 and 1936) are included in these collections of live bait. Specimens which escape from anglers' bait buckets may become established in Lake Mead if they have not done so already. Thus the range of these forms is being extended.

Just outside the recreational area, in the vicinity of the Home Ranch Warm Springs, a few miles west of Glendale, Nevada, two distinctive species are present (Hubbs and Miller, 1941, 1948a, b; Miller, 1946a; Kopec, 1949). These forms, the White River springfish, *Crenichthys baileyi* (Gilbert), and the leather chub, *Moapa coriacea* Hubbs and Miller, are relicts of the ancient White River fauna. During glacial times, this river was a permanent tributary of the Colorado. *Moapa* *coriacea* has not been collected in any other locality. By rigid protection these fishes can be saved from the probable fate of the other indigenous fishes of the Colorado River Basin.

Further investigation of the scattered springs in the recreational area and surrounding regions may reveal other native forms or produce additional distribution records.

EXOTIC FISHES

At least 11 exotic species have been collected in the Lake Mead National Recreational Area.

In addition, the smallmouth black bass, *Micropterus dolomieu* Lacepede, was observed along the shore of Lake Mead near the mouth of Moapa River, July 28, 1942, by Dr. Carl L. Hubbs (Miller and Alcorn, 1946); and the goldfish, *Carassius auratus* (Linnaeus), widely used as a bait fish in the past, may be established. The writer could find no records of either fish being taken from Lake Mead.

Introduced species greatly outnumber the native kinds and are of primary interest to the sportsmen. Exotic game fishes are so firmly established that it has been deemed unnecessary to have a closed fishing season.

Introduction of other alien species into the area does not seem advisable. Additional stocking of largemouth black bass or forage fishes in Lake Mead may prove more detrimental than beneficial. A future survey of existing conditions in Lake Mohave may reveal that the planting of warm-water game fishes in the lower portion of that reservoir is advisable. Although continued stocking of rainbow trout in the cold waters below Hoover Dam will be necessary to support the angling pressure, it is doubtful that trout will prove a satisfactory permanent addition to Lake Mead.

ANNOTATED SPECIES LIST

Salmonidae (Trouts)

Salmo gairdnerii irideus Gibbons, common rainbow trout. For 30 miles below Hoover Dam, in the upper section of Lake Mohave, the rainbow trout is the most important game fish, and this portion of the Colorado is one of the outstanding trout waters of the country. Below this area trout become scarce.

Nearly a million trout fingerlings have been planted, according to National Park Service records. After the initial stocking in 1935, the trout were rigidly protected. When the first season was opened in 1940, fishermen discovered that rainbow trout were prospering in the Colorado River. Eicher (1947) estimated that 20,000 pounds of trout were caught in 1946. The trout average 15 inches in length, but few are over 25 inches (Eicher, 1947). The record trout, which measured 32⅜ inches and weighed 18 pounds, was taken in 1950.

In Lake Mead, where the temperature is generally too warm and other ecological conditions are not favorable, trout are rarely caught and these are strays from plantings made farther up the Colorado River or its tributaries. These trout are usually large, averaging 4 to 5 pounds, and are hooked by fishermen trolling plugs for bass. Periodic agitation by sportsmen's organizations for the planting of trout in Lake Mead arises when such trout are brought in. It is doubtful if such a planting would prove successful from a sportsman's point of view.

Salmo trutta Linnaeus, brown trout. The only record of brown trout in this portion of the Colorado River Basin is that of a specimen caught in the Las Vegas Wash arm on April 6, 1949, by Paul E. Kitcher that was examined by the writer. It weighed 3 pounds 6 ounces, measured 24½ inches in total length, and was in its seventh year of life. This fish had undoubtedly come downstream from stock planted farther up the Colorado.

Catostomidae (Suckers)

Xyrauchen texanus (Abbott), razorback sucker. The razorback or humpback sucker, largest of the native Colorado River suckers, is abundant in Lake Mead and less numerous in Lake Mohave. It appears to have become adjusted to present conditions better than the other native species. In the Lake Mead area, this species exceeds 26 inches in length and 7 pounds in weight.

Pantosteus platyrhynchus (Cope), Bonneville mountain sucker. A single specimen of this exotic species was collected in Lake Mead on September 8, 1938, by Johnny Weston. This fish had undoubtedly been brought to Lake Mead as a bait fish.

Cyprinidae (Minnows, Carp)

Cyprinus carpio Linnaeus, carp. In Lake Mead, the introduced carp has found conditions favorable and has multiplied and spread extensively. It is also found below Hoover Dam. Fishermen are inclined to overestimate their numbers because carp commonly jump and play at the surface.

Permits have been granted to individuals to harvest the carp crop commercially for food and for reduction. The topography of Lake Mead, however, makes seining ineffective as a control measure and gill nets or other types of gear would be equally destructive to game species.

Ptychocheilus lucius Girard, Colorado squawfish. The Colorado squawfish or "white-salmon of the Colorado" is rarely taken. It has been reported from the Lake and from the waters below Hoover Dam (Moffett, 1942, 1943).

Together with other native fishes, the squawfish is becoming less numerous. Formerly, it was abundant in river channels as far north as the base of the Rocky Mountains in Colorado. This fish is the largest of the American minnows, reaching a reputed weight of 80 pounds and length of 5 feet (Jordan and Evermann, 1896), but no such gigantic specimen has been taken in recent years. E. H. Emery, concessioner at Eldorado Landing, told the author that in 1945 a squawfish which weighed 27 pounds was brought into the dock. National Park Service files credit H. Armitage with the capture of a 34-pound "salmon" from this area.

Gila robusta elegans Baird and Girard, bonytail. The bonytail, a native minnow of the Colorado River system, is found in Lake Mead and below Hoover Dam. In earlier days, it was more abundant than now, when it is rarely seen or taken by fishermen. Moffett (1943) reported that he saw rather large schools of bonytails in 1941. Locally the bonytail is known, also, as "Gila or Verde trout," a name which properly applies to the related *Gila robusta robusta.*

Ameiuridae (Catfish)

Ictalurus lacustris punctatus (Rafinesque), southern channel catfish. The channel catfish occurs in Lake Mead, in Moapa River, and in the waters below Hoover Dam (Moffett, 1942, 1943; Miller and Alcorn, 1946). Above Pierce Ferry, near the head of Lake Mead, this fish is common. It is an important game fish in Lake Mead but it is not as plentiful below Hoover Dam.

The first introductions of this species into the Colorado River appear to have been made in 1892-1893, when 722 adults and yearlings, received by the Arizona Fish Commission, were released (Worth, 1895). No stocking of catfish has been made in recent years in this portion of the Colorado River.

A 20-pound, 31-inch catfish, caught in April, 1945, near Pierce Ferry, appears to be the record for Lake Mead.

Ameiurus melas (Rafinesque), black bullhead. On August 2, 1937, R. E. Rees collected the single specimen of the black bullhead recorded from the area. This fish, which measured 159 millimeters in standard length, was caught in Hemenway Wash (near Boulder Beach). Edward Berry, Temple Bar, Arizona, concessioner, told the writer that bullheads were formerly taken in that portion of the lake, but that in recent years none have been brought into the landing. Miller and Alcorn (1946) reported the collection of two young of the southern black bullhead, *Ameiurus melas catulus* (Girard), from Las Vegas Creek at Las Vegas, Nevada, August 30, 1938.

Poeciliidae (Livebearers)

Gambusia affinis affinis (Baird and Girard), western gambusia. This species is found in Moapa River and in the shallow waters of the coves and washes along the shore line of Lake Mead (Moffett, 1943; Miller and Alcorn, 1946). It may have entered Lake Mead via the Moapa or the Virgin River.

Centrarchidae (Sunfishes)

Micropterus salmoides salmoides (Lacepede), largemouth black bass. First extensive plants of largemouth black bass were made in the Colorado River in the Lake Mead National Recreational Area in July, 1935. National Park Service records show that 466,000 bass fingerlings were released into the lake from 1935 to 1940. Today, the largemouth is the principle sport fish of Lake Mead. It is so firmly established in the Lake that further plantings will probably not improve fishing.

This bass is found in the Moapa River (Miller and Alcorn, 1946) and in the waters below Hoover Dam (Moffett, 1942; Dill, 1944).

A short time after its creation, Lake Mead began to receive national recognition for its excellent bass fishing. A 13-pound 14-ounce bass, largest reported from Lake Mead, on November 26, 1939, won first place in the 1939 national *Field* and *Stream* contest. Lake Mead has produced 13 additional place winners since 1939.

Poxomis nigro-maculatus (LeSueur), black crappie. No definite planting records for this species are contained in the National Park Service files; probably, it was stocked in Lake Mead between 1935 and 1937. The black crappie is an important game fish which is found in all parts of Lake Mead but it is rare below Hoover Dam. The fish average between 1 and 2 pounds in weight and under 12 inches in length.

Lepomis macrochirus macrochirus Rafinesque, bluegill. The only planting of bluegills was made in 1937, when 25,000 2-inch fingerlings were released. Now the bluegill is an abundant and important game fish in Lake Mead.

Lepomis cyanellus Rafinesque, green sunfish. Specimens of this species have been collected and examined by the author from all portions of Lake Mead, where it is nearly as numerous and widespread as the bluegill. Moffett (1942, 1943) did not mention its occurrence in this area. Miller and Alcorn (1946) first reported the green sunfish from the Moapa River and from along the shores of Lake Mead near the mouth of the Moapa River.

This fish was probably introduced unintentionally along with the bluegill planted in 1937. The green sunfish is considered less desirable because of the small size it attains and because it is a food competitor.

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GROWTH RATE OF FOUR SPECIES OF FISH IN A SECTION OF THE MISSOURI RIVER BETWEEN HOLTER DAM AND CASCADE, MONTANA[1]

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Abstract

A study of age and growth rates of four species of fish taken from the Missouri River between Holter Dam and Cascade, Montana, was made during the summers of 1948 and 1949. Four hundred and seventy-eight rainbow trout, 127 brown trout, 87 longnose suckers, and 223 western white suckers were examined. Age groups of rainbow trout ranged from I to VII; brown trout, I to IX; longnose suckers, III to VIII; western white suckers, I to VIII. Age group II was most predominant in rainbow and brown trout, group VI in longnose suckers, and group III in western white suckers. Greatest growth was attained during the second year in rainbow and brown trout, and during the first and third years for longnose and western white suckers, respectively. Trout growth is more rapid than sucker growth. The majority of trout were represented in age groups I-III, while suckers were predominantly represented in age groups IV-VIII. Coefficient of condition for 481 rainbow trout was 37.2 and for 117 brown trout was 34.6.

Introduction

During the summers of 1948 and 1949 a fisheries survey was conducted on a section of the Missouri River between Holter Dam and Cascade, Montana. Since no previous fisheries investigations on this part of the river were known to the writer, a study of the growth characteristics of some of the more important species was undertaken to assist in an evaluation of management problems.

Rainbow trout *(Salmo gairdnerii)* and brown trout *(Salmo trutta)*, which are the most important game fish in this section of the river, and longnose sucker *(Catostomus catostomus)* and western white sucker *(Catostomus commersonnii sucklii)*, two of the more important forage species, were examined.

There are 35 miles of stream between Holter Dam and Cascade. The upper 15 miles of this stretch traverse a narrow valley of meadow land. Below this area the river first flows through a canyon for 8 miles and then through an open valley of farm land for the remaining distance. The gradient in this section of river is relatively low with a fall of 3.1 feet per mile. In other respects the river is similar to other streams of the region.

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METHODS OF SAMPLING AND ANALYSIS

The majority of fish examined were taken by angling, but some were secured with gill nets, seines, and dynamite. Total lengths were measured to the nearest 0.1 inch and weights were determined to the nearest 0.1 pound. Scales taken from the left side of the fish, between the dorsal fin and lateral line, were cleaned and mounted in a glycerine-gum arabic medium, and were analyzed and measured on a scale-projection machine. Scale measurements of rainbow and brown trout were made for the center of the focus along the median-anterior radius. Sucker scales were measured along the dorso-ventral diameter as described by Spoor (1938). Coefficients of condition (C) were calculated for the rainbow and brown trout from the formula:

$$C = \frac{W \times 10^5}{L^3}$$

where W = weight in pounds, and L = total length in inches.

AGE AND RATE OF GROWTH

The age was assessed and growth rates were determined for 478 rainbow trout, 127 brown trout, 87 longnose suckers, and 223 white suckers. Since the samples were taken at various times during the growing season, calculations were made to determine lengths at the end of each year of life. These calculations were based on the assumption of a rectilinear relationship between body length and scale length and included no correction for length of fish at time of scale formation. Calculated lengths have been expressed for each age group and as grand averages for all groups.

TABLE 1.—*Average calculated total lengths and increments of rainbow trout collected in 1948 and 1949 from the Missouri River—expressed as inches.*

Age group	Number fish	Average length at capture	Year of life						
			1	2	3	4	5	6	7
I	107	8.8	3.6						
II	202	11.7	3.2	8.3					
III	129	13.3	3.2	7.6	10.9				
IV	36	15.1	3.3	7.1	11.0	13.4			
V	2	18.5	4.1	7.7	11.6	15.3	17.6		
VI	1	18.1	4.3	7.7	11.4	15.2	15.9	17.1	
VII	1	19.7	3.7	6.5	8.5	10.0	12.5	16.0	18.5
Grand average calculated length			3.2	7.9	11.1	13.5	15.9	16.6	18.5
Increment			3.2	4.7	3.2	2.4	2.4	0.7	1.9
Number of fish	478		478	371	168	40	4	2	1

TABLE 2.—*Average calculated total lengths and increments of brown trout collected in 1948 and 1949 in the Missouri River—expressed as inches.*

Age group	Number fish	Average length at capture	Year of life								
			1	2	3	4	5	6	7	8	9
I	17	8.3	4.9	......	......	......	......	......	......	......	......
II	36	11.0	3.6	8.5	......	......	......	......	......	......	......
III	26	13.7	3.8	8.2	12.0	......	......	......	......	......	......
IV	29	16.2	3.9	8.0	12.0	14.9	......	......	......	......	......
V	14	19.1	3.8	7.9	12.8	15.0	18.1	......	......	......	......
VI	2	21.4	3.7	8.0	12.3	16.4	18.7	20.4	......	......	......
VII	1	23.5	5.0	8.4	12.3	16.3	19.2	21.5	22.5	......	......
VIII	1	24.4	3.8	7.8	11.6	16.8	20.3	22.0	23.3	24.2	......
IX	1	21.6	3.4	5.3	9.5	12.4	15.1	17.0	19.0	20.2	21.6
Grand average calculated length	....	....	3.9	8.1	12.0	15.3	18.2	20.0	21.7	22.2	21.6
Increment	....	....	3.9	4.2	3.9	3.3	2.9	1.8	1.7	0.5	......
Number of fish	127	....	127	103	71	47	19	5	3	2	1

Rainbow Trout.—The grand average calculated lengths for rainbow trout at the end of each succeeding year of life for 7 years were 3.2, 7.9, 11.1, 13.5, 15.9, 16.6, and 18.5 inches, respectively (Table 1). Growth rate was greatest in the second year, but did not decline appreciably until after the third year. This growth rate is substantially better than the average total lengths of rainbow trout in age groups I and II from three Michigan streams, as reported by Shetter and Hazzard (1939). Small samples of fish in the age groups beyond 4 years may result in some error in this range. The population as represented by the samples was comprised principally of the younger age classes. Ninety-two percent of the fish were represented in age groups I-III, with the largest number age group II.

Brown trout.—Brown trout grew at a substantially faster rate than did the rainbows. The average calculated lengths of brown trout at the end of each year of life for the first 9 years were 3.9, 8.1, 12.0, 15.3, 18.2, 20.0, 21.7, 22.2, and 21.6 inches respectively (Table 2). Growth was rapid during the first 3 years of life, with the greatest growth occurring during the second year. There was a gradual decrease in growth increments for each year of life beyond the second year. Average lengths of brown trout from the Missouri River were greater than those of brown trout taken in Crystal Creek, New York, by Schuck (1945).

Age class composition of the brown trout population was more uniform than in the rainbow population and the older groups were much more strongly represented. Sixty-two percent of the sample was represented by age groups I-III, and 28 percent was represented by age groups V-IX. The largest number was represented by age group II, closely followed by age groups III and IV.

TABLE 3.—*Average calculated total lengths and increments of longnose suckers collected in 1948 and 1949 in the Missouri River—expressed as inches.*

Age group	Number fish	Average length at capture	Year of life							
			1	2	3	4	5	6	7	8
I	0	......	......	......	......	......	......	......	......	......
II	0	......	......	......	......	......	......	......	......	......
III	3	12.9	2.6	6.5	11.0	......	......	......	......	......
IV	10	13.4	3.0	6.1	9.2	12.0	......	......	......	......
V	19	14.7	3.4	6.5	9.0	11.5	13.6	......	......	......
VI	28	15.3	3.2	5.5	8.0	10.5	12.5	14.2	......	......
VII	19	15.7	2.6	4.7	7.2	8.9	11.4	13.4	15.0	......
VIII	8	16.3	2.8	4.4	6.3	8.4	10.5	12.4	14.1	15.5
Grand average calculated length	......	......	3.0	5.5	8.1	10.4	12.3	13.7	14.7	15.5
Increment	......	......	3.0	2.5	2.6	2.3	1.9	1.4	1.0	0.8
Number of fish	87	......	87	87	87	84	74	55	27	8

Rainbow and brown trout both showed their greatest growth during the second year of life. Increments of growth were progressively less in brown trout after the second year, but there was no progressive decrease shown by rainbow trout. Growth increments in brown trout were greater than those in rainbow trout in all years except the fifth and seventh. The samples representing these 2 years were small for both species, and may not be representative. The growth of both rainbow and brown trout in this section of the Missouri River is as good or better than that of the same species in certain other trout streams of Montana as revealed by unpublished survey data from these waters.

Longnose Suckers.—The longnose sucker which is an important component of the fish population of the upper Missouri River has slower growth than has been observed in some other water. The average calculated lengths for this species at the end of each year of life for

TABLE 4.—*Average calculated total lengths and increments of western white suckers collected in 1948 and 1949 in the Missouri River—expressed as inches.*

Age group	Number fish	Average length at capture	Year of life							
			1	2	3	4	5	6	7	8
I	9	5.6	2.5	......	......	......	......	......	......	......
II	22	7.4	2.6	5.2	......	......	......	......	......	......
III	62	10.9	2.5	5.8	9.2	......	......	......	......	......
IV	42	11.9	2.4	5.1	7.5	10.0	......	......	......	......
V	40	13.4	2.6	5.0	7.2	9.7	12.0	......	......	......
VI	32	15.0	3.0	5.9	8.7	11.0	12.6	14.2	......	......
VII	11	14.8	2.5	4.9	6.9	9.0	11.8	13.8	14.1	......
VIII	5	16.0	2.6	4.4	6.8	8.9	11.0	12.6	14.1	15.2
Grand average calculated lengths	......	......	2.6	5.3	8.2	10.1	12.2	13.7	14.1	15.2
Increment	......	......	2.6	2.7	2.9	1.9	2.1	1.5	0.4	0.9
Number of fish	223	......	223	214	192	131	90	49	17	5

TABLE 5.—*Average coefficient of condition* (C) *for rainbow and brown trout collected in 1948 and 1949 in the Missouri River.*

Species & item	Age group							
	I	II	III	IV	V	VI	VII	VIII
Rainbow trout.....	36.9	37.7	37.1	35.5	34.2	29.5	....	....
Number of fish.....	113	205	125	35	2	1	....	....
Brown trout.......	36.3	33.6	33.4	34.6	36.6	37.0	37.4	19.8
Number of fish	21	30	24	26	12	2	1	1

the first 8 years are 3.0, 5.5, 8.1, 10.4, 12.3, 13.7, 14.7, and 15.5 inches respectively (Table 3). Growth was greatest during the first year and decreased progressively as the fish grew older. Ninety-five percent of all samples are in age groups IV-VIII, with the largest number in age group VI. No fish in age groups I and II were taken.

Western White Sucker.—The western white sucker which was represented by a good sample grew at a rate similar to that of the longnose sucker. The average calculated lengths at the end of each year of life for the first 8 years were 2.6, 5.3, 8.2, 10.1, 12.2, 13.7, 14.3, and 15.2 inches respectively (Table 4). The most rapid growth occurs in the third year of life. Apparent variations in the rate of increment in older fish are attributed to the small size of samples in these groups. Growth increments were greater for the longnose sucker than the white sucker in the first year. After the first year, the average calculated lengths at the end of each year of life were very nearly identical. Fifty-eight percent of all samples were represented in age groups IV-VIII, with the largest number found in age group III.

COEFFICIENT OF CONDITION

Condition factor (C) in rainbow trout ranged from 36.9 in age group I to 29.5 in age group VI with an average of 37.2 (Table 5). The decline was steady as the fish grew older, but small numbers of fish in the older groups make any appraisal of significance difficult. The condition (C) of the brown trout was very similar to that of the rainbows and ranged from 36.3 in age group I to 19.8 in age group VIII, with an average of 34.6. Except for the VII and VIII year groups condition appeared to improve as the fish grew older but small samples here also cast doubt on the validity of the observation in the older groups.

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FOOD HABITS OF THE YELLOWSTONE WHITEFISH *PROSOPIUM WILLIAMSONI CISMONTANUS* (JORDAN)[1]

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Abstract

A quantitative analysis of the food habits of 385 whitefish *(Prosopium williamsoni cismontanus* (Jordan)) and 52 trout from the Yellowstone and Gallatin Rivers was made. Collections were taken over a period of 1 year beginning in September, 1947, on the Yellowstone and on the Gallatin Rivers. Fingerling whitefish used the same food organisms as did adults but consumed smaller numbers and sizes. There was no important difference in the kinds of foods eaten by whitefish of different lengths. Caddis larvae and stonefly nymphs made up about equal parts of the whitefish diet. Midges were next in importance and mayflies comprised the smallest volume. Caddisflies and Diptera larvae together constituted 87 percent of the total number of organisms consumed. Whitefish in the Yellowstone ate mostly immature caddis- and stoneflies, while the Gallatin fish utilized caddis, fish eggs, Diptera, stoneflies, and mayflies in more nearly equal amounts. Seasonal variations found in the diet of whitefish show that caddis was important in the fall and winter, stoneflies were abundant except in the fall, mayflies were most numerous in the spring, and midges were numerous in the food throughout the year.

Introduction

The Yellowstone whitefish, *Prosopium williamsoni cismontanus* (Jordan), a protected game species in Montana, has received scant attention from fishery workers. Because this species is potentially an important element of game-fish fauna in the state, a series of studies on the basic ecological and fishery relationships was initiated at Montana State College. The present study has attempted to determine some of the food relationships of the whitefish and competing species. Data are derived from the analysis of stomach contents of 385 whitefish, 33 rainbow trout, and 19 brown trout collected on the Yellowstone and Gallatin Rivers during a 1-year period beginning in September, 1947. The 65-mile portion of the Yellowstone River sampled, extends from Corwin, 6 miles north of the Yellowstone National Park boundary, to a point 15 miles northeast of Livingston. This section of the river flows north through a narrow valley between the Absaroka and Gallatin ranges to Livingston and then flows in a northeast direction. The water level is more constant than in the Gallatin River, and the peak of the spring flood usually occurs in June. During severe winter weather, shore ice extends some distance over the water, but the main channel always

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remains open. In the Gallatin River sampling was done in a 25-mile section extending from Williams Bridge near the mouth of the Gallatin Canyon to the bridge east of Manhattan. This portion of the river flows north along the western edge of Gallatin Valley. The volume of water in summer is greatly reduced in the lower two-thirds of this section because much is removed for irrigation. Winter conditions in the Gallatin River are comparable to those in the Yellowstone. A limited number of whitefish were obtained from the Missouri River one-half mile below the confluence of the Madison and Jefferson rivers. The area sampled is near Trident, about one-half mile upstream from the mouth of the Gallatin River. A few specimens were also taken directly in the mouth of the Gallatin.

The whitefish is distributed throughout the cold headwaters of the Missouri River drainage. In this area it is associated with cutthroat trout *(Salmo clarkii)*, rainbow trout *(Salmo gairdnerii)*, brown trout *(Salmo trutta)*, eastern brook trout *(Salvelinus fontinalis)*, white sucker *(Catostomus commersonnii)*, carp *(Cyprinus carpio)*, longnose dace *(Rhinichthys cataractae)*, burbot *(Lota lota)*, and freshwater sculpin *(Cottus* sp). Additional species which may occur in the Yellowstone and Gallatin rivers and which are known to occur in the Missouri River include flathead chub *(Platygobio gracilis)*, yellow perch *(Perca flavescens)*, and stonecat *(Noturus flavus)*.

No previous food-habits work on the subspecies of whitefish discussed here has been done, but McHugh (1940) has studied the food habits of another form of whitefish in a different area. Various studies have been made on trout in the inter-mountain region (Hazzard and Madsen, 1933; Muttkowski, 1925). However, no observations on competition between the whitefish and these species have been recorded by these authors.

METHODS OF COLLECTING AND STOMACH ANALYSIS

Angling was found to be the only practical method of obtaining specimens of mature fish for stomach analysis since the size and rugged nature of the streams made the use of seines or other nets impractical. Angling was selective to a certain degree since no fish smaller than 7 inches was taken by this means. It is also possible that non-feeding individuals or those utilizing foods dissimilar to baits offered, were omitted from the collections. Immature aquatic insects, particularly stonefly nymphs, were the most commonly used bait but fly maggots were also an effective bait in winter. At certain seasons, earthworms, grasshoppers, and small dry-flies yielded good catches. During June and July, fingerling whitefish were seined from shallow water near shore in the Yellowstone River but none was found in the same areas later in the summer.

Collections of aquatic food organisms from most of the fish sampling stations were made to assist in the identification of partially digested material found in the stomachs of whitefish and trout.

In order to prevent post-mortem decomposition of food items, viscera were removed and preserved in 10 percent formalin within a few minutes after the fish were caught. When temperatures were low, removal of viscera was sometimes delayed a few hours without danger of decomposition. All material in the stomach and oesophagus of each fish was later emptied into a vial and stored in 80 percent alcohol. The contents of each stomach were classified and all recognizable items were identified and counted. Items which could be clearly identified as bait were discarded. Each group of organisms was placed on blotting paper for 2 minutes to remove excess moisture and then its volume was determined by displacement in alcohol. Volumes smaller than 0.1 milliliters were reported as "traces." Unidentifiable material was separated from the rest and measured in the same way.

THE FOOD OF FINGERLING WHITEFISH

Two collections of fingerling whitefish were seined at Carters Bridge on the Yellowstone River. The fish in the first sample collected on June 22 averaged 1¼ inches in total length, while the second group taken a month later averaged 2 inches. Stomach analyses showed the dependence of young whitefish on aquatic insects. The principal item of food was midge larvae, but relatively large numbers of adult chironomids were also taken (Table 1). *Baetis* nymphs, immature stoneflies, and caddis larvae were also important items in the diet. There was no apparent difference in number or kinds of food organisms utilized by the fingerlings of the two size classes.

FOOD OF THE ADULT WHITEFISH IN THE YELLOWSTONE RIVER

The food of adult whitefish, although composed almost entirely of immature insects, was quite different from that taken by fingerlings. In the Yellowstone River 81.1 percent by weight of all food taken

TABLE 1.—*Stomach contents of 35 fingerling whitefish taken from the Yellowstone River in June and July.*

Food organism[1]	June 22		July 21	
	Average number per stomach	Percentage of fish with organism	Average number per stomach	Percentage of fish with organism
Plecoptera	....	....	1.0	15.4
Ephemeroptera	2.0	52.0	1.0	77.0
Psychomyiidae	1.5	8.0	....	....
Hydropsychidae	1.0	8.0	1.0	7.7
Simuliidae	....	....	1.0	7.7
Chironomidae				
Larvae	32.2	100.0	25.8	100.0
Pupae	3.0	32.0	8.3	77.0
Adults	2.7	72.0	1.0	23.0

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[1] Plecoptera, Psychomyiidae, Hydropsychidae, and Simuliidae were taken in the immature state. Ephemeroptera occurred as nymphs, subimagoes, and adults.

TABLE 2.—*Food of adult whitefish at different seasons*[1] *in the Yellowstone River.*
(Percentages of fish containing each group are enclosed in parentheses)

Food Organisms[2]	September—November			December—February			March—May			June—August		
	Average number per fish	Percentage of total volume		Average number per fish	Percentage of total volume		Average number per fish	Percentage of total volume		Average number per fish	Percentage of total volume	
Annelida (Worms)	...	...		...	...		...	...		...	...	
Mollusca (Snails)	2.0	Trace	(4.3)	...	...		...	...		...	...	
Diplopoda (Millipedes)	...	...		...	...		...	...		...	...	
Plecoptera (Stoneflies)												
Pteronarcys californica	...	...		...	...		1.0	16.7	(33.3)	6.0	36.5	(11.1)
Pteronarcella badia	3.0	2.5	(43.5)	1.5	1.2	(16.0)	4.0	16.7	(33.3)	1.0	1.1	(5.6)
Acroneuria pacifica	...	...		...	...		...	...		1.0	1.1	(5.6)
Perlodidae	5.1	11.2	(65.2)	2.6	3.4	(27.0)	...	...		...	...	
Isoperla	9.5	0.2	(56.5)	13.4	4.0	(56.0)	4.0	5.5	(33.3)	1.0	Trace	(5.6)
Ephemeroptera (Mayflies)												
Heptageniidae	3.5	0.8	(43.5)	3.6	1.2	(40.0)	...	...		13.2	3.4	(55.6)
Baetidae	5.7	3.7	(78.3)	7.3	3.4	(80.0)	4.0	16.7	(67.7)	52.8	50.0	(100.0)
Coleoptera (Beetles)												
Aquatic larvae	...	...		...	...		...	...		...	...	
Trichoptera (Caddisflies)												
Rhyacophila	...	...		1.0	Trace	(4.0)	3.0	5.6	(33.3)	...	...	
Glossosoma	3.6	0.5	(21.8)	29.4	10.9	(60.0)	78.5	38.8	(67.7)	2.5	Trace	(11.1)
Psychomyiidae	...	...		...	...		...	...		...	...	
Hydropsychidae	6.6	4.5	(78.3)	6.1	7.5	(60.0)	1.0	Trace	(67.7)	...	...	
Hydroptilidae	4.0	Trace	(4.3)	8.0	Trace	(28.0)	...	...		...	...	
Leptoceridae	4.0	0.2	(13.1)	...	...		1.0	Trace	(33.3)	8.0	Trace	(11.1)
Brachycentridae	11.4	10.4	(87.0)	2.4	0.6	(28.0)	1.0	Trace	(33.3)	8.3	4.6	(83.4)
Neothremma, Lepidostoma	154.8	18.2	(95.7)	24.1	2.9	(60.0)	...	...		2.0	Trace	(5.6)
Lepidoptera (Moths)												
Elophila	...	...		...	...		...	...		...	...	
Diptera (True Flies)												
Tipulidae	1.8	2.0	(26.5)	1.0	1.2	(4.0)	...	...		...	...	
Bibiocephala	...	...		1.7	0.6	(12.0)	...	...		...	...	
Simuliidae L and P	17.2	0.5	(60.8)	67.0	3.4	(32.0)	...	...		5.3	1.1	(44.4)
Chironomidae L and P	36.5	1.5	(47.8)	195.0	55.6	(100.0)	3.0	Trace	(33.3)	13.9	1.1	(55.6)
Chironomidae Adults	...	...		1.3	Trace	(28.0)	...	...		3.0	Trace	(5.6)
Atherix	1.0	Trace	(4.3)	...	...		...	...		...	...	
Hymenoptera												
Formicidae (Ants)	...	...		...	...		...	...		4.0	1.1	(5.6)
Hydracarina (Water mites)	...	...		...	...		...	...		10.9	Trace	(38.8)
Vertebrata												
Fish	...	...		...	...		...	...		...	...	
Fish eggs	31.3	43.8	(95.7)	4.0	4.0	(20.0)	...	...		...	...	
Average identifiable stomach volume (Milliliters)		1.75			.70			.60			.49	

[1] The data for each season are based on the following number of stomachs: Fall—85; Winter—85; Spring—60; Summer—31.

[2] All food insects not having the stage of development indicated, were taken in the immature stage except for the following: mayflies—nymphs, subimagoes, adults; Glossosoma—larvae, pupae; Brachycentridae—larvae, pupae, adults; Bibiocephala—larvae, pupae, adults; Formicidae—adults.

Unidentifiable material constituted the following percentages of the total volume of stomach contents: fall—74.2 percent; winter—22.6 percent; spring—48.5 percent; summer—57.5 percent.

throughout the year was composed of approximately equal amounts of the immature stages of caddisflies and stoneflies (Table 2). True flies including midges made up almost 10 percent of the volume. Caddis larvae were the most numerous and frequent item in the stomachs. Hydropsychidae were the commonest representative of the group and made up about one-fourth of the average diet. Midges predominated in the fall collections (32.2 percent by volume) and *Brachycentrus* were second with a volume of 24.2 percent (Table 2). Cases of *Brachycentrus* were included in the volume measurement of the first 40 whitefish studied. In later collections, the cases were removed in order to measure digestible material more accurately. To correct these early measurements, a factor was established by comparing volumes of cased and uncased larvae from 17 stomachs containing approximately 680 larvae. The volume of the uncased larvae was found to be 48 percent of the cased larvae. The presence of gravel in some of the stomachs was evidence that *Glossosoma* larvae or pupae, which construct cases of this material, had been eaten and digested.

Lepidostoma and *Neothremma* which appeared in large numbers in the stomachs of Yellowstone fish, were not considered separately because they were difficult to identify. The microcaddis, Hydroptilidae,

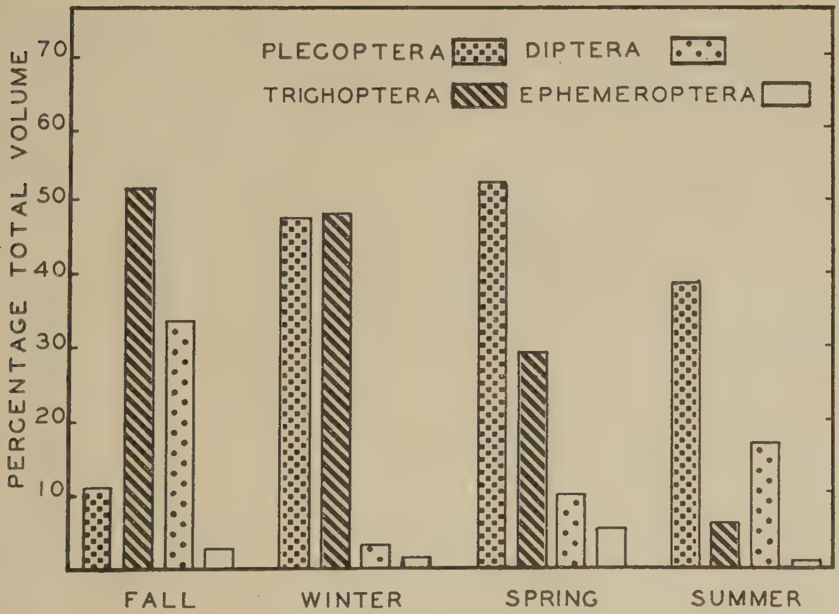

FIGURE 1.—Abundance of important insect food items in the diets of Rocky Mountain whitefish from the Yellowstone River at various seasons—expressed as percentage of total volume.

were also numerous in a few instances. During colder weather, cases with larvae intact were observed in the intestines of several whitefish. Psychomyiidae were most numerous in the diet of spring-caught fish with a few occurring in the fall. A few *Rhyacophila* were found in the spring samples.

Plecoptera nymphs were less common than caddis larvae in whitefish stomachs although their total volume was a little greater. *Isogenus (Isogenoides) elongatus* and *Arcynopteryx parallela* of the family Perlodidae, and *Pteronarcella badia* were abundant in the diet during the winter and spring months. These species contribute little volume in the early summer when they are mostly small in size. The nymphs of these three species were most abundant at the stations below Livingston.

Stream bottom samples and the stomachs of whitefish from the vicinity of Emigrant Creek (elevation 5,000 feet) on the Yellowstone River lacked *Acroneuria* and *Pteronarcys*. They occurred more frequently in the stomachs of whitefish during the summer months at a time when other stoneflies and caddis had emerged. *Acroneuria* and *Pteronarcys* spend at least 2 years as nymphs and are more obvious as food items at the time when other aquatic insects are in the early stages of development.

The small stonefly, *Isoperla*, was fairly common but contributed little to the total volume. The Diptera, which were largely Chironomidae and *Bibiocephala*, made up 7 percent of the total volume of whitefish food. Chironomids were more numerous than any other organism. Approximately 96 percent of the fall collection contained midge larvae and pupae (Figure 1). A smaller number of midges occurred in stomachs collected at other seasons. Adults were seen frequently on shore ice in January and February. The stomach of one whitefish collected at this season contained 35 adult midges. *Bibiocephala* was most common in the winter and occurred in one-third of the stomachs. A specimen taken on March 4 at Carters Bridge, 5 miles above Livingston, contained 153 of these larvae. Simuliidae were eaten by whitefish in small numbers throughout the year. About 90 percent of the total recorded for the year were in the stomach of one fish caught at Carters Bridge in July.

Ephemeroptera observed in the diet of whitefish included *Heptagenia, Ephemerella, Baetis, Ameletus,* and *Rhithrogena*. These nymphs occurred rather frequently in the stomachs during the year but made up less than 2 percent of the total volume and less than 4 percent of the total number.

Whitefish eggs were found in the stomachs of 16 fish taken during the fall and winter. The largest number occurred in specimens taken below Livingston on January 2. Fewer eggs were found in the stomachs of Yellowstone whitefish than in the Gallatin River specimens, possibly because the collections did not coincide with actual spawning. A few ants, leaf hoppers, earthworms, and a millipede constituted the

TABLE 3.—*Food of adult whitefish at different seasons*[1] *in the Gallatin River.*
(Percentages of fish containing each group are enclosed in parentheses)

Food Organisms[2]	September—November		December—February		March—May		June—August	
	Average number per fish	Percentage of total volume	Average number per fish	Percentage of total volume	Average number per fish	Percentage of total volume	Average number per fish	Percentage of total volume
Annelida (Worms)							2.8	27.9 (12.9)
Mollusca (Snails)			1.0	Trace (1.2)				
Diplopoda (Millipedes)					1.0	Trace (1.7)		
Plecoptera (Stoneflies)								
Pteronarcys californica			1.0	0.4 (1.2)	4.0	7.1 (5.0)	2.0	33.9 (45.1)
Pteronarcella badia	1.0	Trace (3.6)	13.7	25.5 (64.8)	6.0	21.4 (48.4)	1.5	0.9 (6.5)
Acroneuria pacifica			4.3	0.9 (3.5)	1.8	2.2 (8.3)	1.0	4.2 (19.4)
Perlodidae	2.1	11.0 (49.4)	9.9	21.1 (60.0)	5.7	21.9 (48.4)		
Isoperla	2.1	Trace (17.6)	2.7	Trace (23.5)	2.0	Trace (23.3)	1.0	Trace (6.5)
Ephemeroptera (Mayflies)								
Heptageniidae	2.5	Trace (15.3)	4.7	0.4 (38.8)	2.7	Trace (35.0)	1.0	Trace (12.9)
Baetidae	10.5	2.1 (28.3)	3.0	0.4 (28.2)	11.6	5.1 (66.7)	3.5	0.9 (32.2)
Coleoptera (Beetles)								
Aquatic larvae	1.0	Trace (1.2)	1.0	Trace (2.4)	1.0	Trace (1.7)	2.6	9.3 (16.1)
Trichoptera (Caddisflies)								
Rhyacophila					1.0	Trace (3.3)		
Glossosoma	8.1	3.8 (65.8)	4.4	0.4 (28.2)	4.7	0.5 (25.0)	1.0	Trace (3.2)
Psychomyiidae	2.8	Trace (4.7)			26.0	Trace (10.0)		
Hydropsychidae	8.9	11.5 (78.8)	57.0	31.6 (86.0)	7.7	7.9 (96.7)	4.3	4.2 (71.0)
Hydroptilidae	4.6	0.4 (42.4)	3.6	Trace (11.8)	64.1	2.8 (31.6)		
Leptoceridae	3.6	0.4 (9.4)	1.4	Trace (5.9)	2.2	Trace (8.3)		
Brachycentridae	9.4	24.2 (55.4)	27.5	14.7 (64.8)	12.9	9.6 (60.0)	7.0	1.7 (16.1)
Neothremma, Lepidostoma	40.5	13.2 (76.5)	27.3	1.3 (65.9)	46.1	8.5 (71.7)	3.0	Trace (3.2)
Lepidoptera (Moths)								
Elophila			1.0	Trace (3.5)				
Diptera (True Flies)								
Tipulidae	1.0	0.4 (2.4)	1.3	Trace (3.5)	1.0	0.5 (10.0)		
Bibiocephala	2.2	0.8 (10.6)	1.5	0.9 (32.9)	23.1	4.8 (11.7)		
Simuliidae L and P	2.3	Trace (9.4)	6.1	Trace (14.1)	3.5	Trace (3.3)	130.1	14.4 (22.6)
Chironomidae L and P	53.1	32.2 (96.5)	50.1	1.8 (61.2)	53.2	4.4 (65.0)	16.8	1.7 (77.4)
Chironomidae Adults	1.2	Trace (5.9)	35.0	Trace (1.2)	3.1	Trace (1.7)	4.0	Trace (3.2)
Atherix	1.0	Trace (3.6)	1.3	0.3 (4.7)	1.0	Trace (5.0)	2.5	0.9 (6.5)
Hymenoptera								
Formicidae (Ants)					3.5	Trace (3.3)	1.3	Trace (12.9)
Hydracarina (Water mites)								
Vertebrata								
Fish					2.0	3.3 (1.7)		
Fish eggs	1.0	Trace (2.4)	2.2	0.3 (16.5)	1.0	Trace (1.7)		
Average identifiable stomach volume (Milliliters)		.81		.76		1.24		.51

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[1] The data for each season are based on the following number of stomachs: Fall—23; Winter—25; Spring—3; Summer—18.

[2] All food insects not having the stage of development indicated, were taken in the immature stage except for the following: mayflies—nymphs, subimagoes, adults; *Glossosoma*—larvae, pupae; Brachycentridae—larvae, pupae, adults; *Bibiocephala*—larvae, pupae, adults; Formicidae—adults.

Unidentifiable material constituted the following percentages of the total volume of stomach contents: fall—24.5 percent; winter—55.1 percent; spring—83.0 percent; summer—40.5 percent.

terrestrial food taken by whitefish from the Yellowstone River. These were found in all except the winter season.

FOOD OF WHITEFISH FROM THE GALLATIN RIVER

Caddisflies and stoneflies were conspicuous in the diet of Gallatin River whitefish but did not predominate to the same extent as in the Yellowstone River. Trichoptera larvae comprised approximately 27 percent of the volume of all food taken by whitefish from the Gallatin River through the year (Table 3). *Lepidostoma* and *Neothremma* were the most abundant representatives of this group. Their numbers were greatest in the fall collection. *Brachycentrus* larvae and pupae were likewise most frequent at this season. Adults belonging to this genus were present in 8 out of 13 whitefish collected at Cameron Bridge on July 29. Caddis of the family Hydropsychidae were less conspicuous and formed only one-sixth of the total volume of caddis found in the diet.

The volume of whitefish eggs was the largest single item in the autumn food. All but one of the stomachs from the collections of fish made November 16 and 23 contained fish eggs. Two brown-trout eggs were

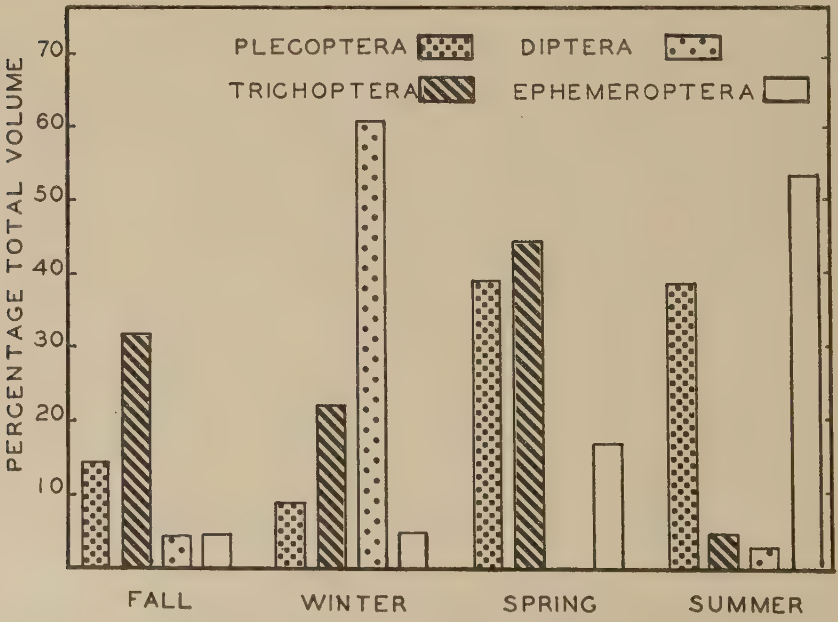

FIGURE 2.—Abundance of important insect food items in the diets of Rocky Mountain whitefish from the Gallatin River at various seasons—expressed as percentage of total volume.

present in the stomach of one whitefish. Midges occurred in every fish taken during the winter. At this season they were the most important item in the diet (55.6 percent) and made a much greater contribution than in the Yellowstone River. Adults were observed in stomachs of fish which were taken in January, February, and July.

The Perlodidae and *Pteronarcella* contributed most to the volume of stonefly nymphs taken during the fall season, while *Isoperla* was most prevalent in the diet of specimens collected in January and February. As in the Yellowstone River, a large volume of *Pteronarcys* was present in the stomach contents of fish taken in June and July. Mayflies made up about 11 percent of the total volume of food taken by whitefish in the Gallatin River collections as compared to 2 percent for the Yellowstone. They were most numerous in the stomachs of fish caught at Cameron Bridge in July. A collection of 14 fish from this locality contained an average of 62 nymphs. The contents of one stomach was composed of 130 subimagoes and adults almost to the exclusion of other items.

A greater use of surface food during the spring season and the consumption of more fish eggs in the fall months was characteristic of Gallatin River whitefish (Figure 2). Stomach examinations revealed more nearly representative volumes of available aquatic insects in the fish from the Gallatin than those from the Yellowstone River where stonefly nymphs and caddis larvae represented more than 80 percent of the total food volume.

A collection of 60 whitefish taken in January on the Yellowstone River was divided into three groups on the basis of size. The stomach content of each group was compared with the others. No important differences in the kinds of food organisms utilized by the different sizes could be observed. The percentage of stonefly nymphs was a little greater in the stomachs of the largest fish while the volume of caddis was larger in the group of smallest individuals. The average volume of food per stomach was more than twice as great in the biggest group (over 16 inches total length) than in the smallest group (under 14 inches total length).

Comparison of Whitefish and Trout Food

An effort was made to collect trout from the same localities and at the same time that whitefish were taken in order to make a comparison of their food habits. Only a small number of trout were secured, and while no specific conclusions can be drawn from the limited information obtained, a few observations are of interest.

The proportion of caddis larvae, stonefly nymphs, and whitefish eggs was approximately the same in the stomachs of brown trout and whitefish collected at Manhattan Bridge, on the Gallatin River, November 23. Whitefish eggs were the most abundant item in the diet of both species. On November 29, stoneflies made up 39 percent of the stomach content of five brown trout (9 to 15 inches total length) from Carters Bridge as compared with 15.5 percent for whitefish collected at the same time and place.

No algae were found in the stomachs of whitefish but this material comprised 22.6 percent of the stomach contents of rainbow trout and was taken by 36 percent of the specimens collected. Two rainbow trout (7½ and 10 inches total length) taken near Carters Bridge in October contained a variety of surface food including the adults of mayflies and midges, as well as leaf hoppers, beetles, and ants. Whitefish taken at the same time lacked all of these items. An 18-inch rainbow trout from Carters Bridge in May contained eight *Pteronarcys* nymphs. This species of stonefly was not found in the food of whitefish from the same area at any time during the year.

Only small amounts of food were in the stomachs of whitefish and rainbow trout taken on June 22 at Carters Bridge. This light feeding may have been the result of the high water condition which occurred at that time. Four rainbow trout (8 to 15 inches total length) from this collection contained a small amount of surface food consisting of adult mayflies, *Isoperla,* midges, and ants. One trout of this collection had the remains of a fish in its stomach. Whitefish taken at the same time and place contained earthworm, beetle larvae, caddis larvae, and stonefly nymphs.

Needham (1930) observed that trout fed less actively during the winter when temperatures were low. Whitefish, on the other hand, usually had full stomachs even during the coldest part of the year. A comparison of stomach contents of 124 whitefish and 13 trout taken December to February shows that whitefish contained over five times as much food per stomach as the trout.

Whitefish and Trout Relationships

There is considerable competition for aquatic food organisms by whitefish and trout in the streams which were studied. In the winter, the diets of the two are strikingly similar. However, according to Leonard (1941), the food supply may not be a limiting factor in the success of trout during cold weather since digestion is slow and the amount of nourishment obtained from food is questionable. The condition of foods in the intestine of whitefish also indicates that digestive processes are slower during winter. In the summer, competition is probably keener because food supply is reduced by scouring during the spring "runoff" (Muttkowski, 1929), and because many species of aquatic insects emerge during the season. Trout and whitefish utilize surface organisms as a supplement to aquatic organisms during the summer.

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CONSIDERATIONS FOR AN INTERNATIONAL APPROACH TO TAXONOMY OF MARINE FISH

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Abstract

Due to the confusion and duplication which exist among scientific and common names of important marine fish, the study of the nomenclature of economically important species of fish of the world was undertaken by the Fisheries Division of the Food and Agriculture Organization This work was started with a survey of the papers published on the taxonomy of tunas and mackerels. On careful scrutiny, these papers showed considerable disagreement in the numbers and the distribution of the species dealt with, due mostly to a lack of studies based on sizeable samples collected throughout the range of each species.

Taxonomists, at the beginning of their study of marine fish, had neither help from other disciplines to supplement their studies nor means to get large numbers of specimens from widely separate geographic areas of the world. Consequently, their first works were not as complete as they can be now. Today taxonomy is evolving toward the development of broader approaches for the study of marine fish; however, there is still need for world revisions of many groups of fishes.

It is recommended that taxonomists coordinate their efforts for the study of at least the economically important species of fish on an international basis, as some fishery scientists or biologists are already doing with some degree of success. If such international cooperation were established, larger collections of specimens made throughout the range of a species undoubtedly would reveal the identity of certain species now confusingly considered different because complete data are lacking. Taxonomic research conducted on a wider geographic area and based on larger samples would doubtless result in a reduction in the present number of scientific names of fish, many of which can be, and are, duplications.

A World Nomenclature of Species

Delegates at the first session of the Conference of the Food and Agriculture Organization of the United Nations agreed that the present taxonomic arrangement of the commercial species of fish is unsatisfactory and that a "Nomenclature of Economically Important Species of Fishes of the World" should be prepared by the Fisheries Division of that Organization to make taxonomic works more useful for fishery studies and to the fishery industry. As a biologist with training in taxonomy, I was assigned to this project. Work was initiated with an exploratory study of the literature on tunas and mackerels, since their distribution is world-wide and their commercial value is fast increasing. I found that most of the studies dealt with the species of individual countries or small geographic areas. Three revisions are available, i.e., one by Kishinouye (1923) on the mackerels and tunas of Japan, another by Jordan and Evermann (1926) on the tunas and spearfishes of the world, and a third recent one by Fraser-Brunner (1950), a world revision of the family Scombridae.

Although these revisions were helpful, it was difficult to understand the published data. Most of the authors consulted recognized the fact that several species listed or described by them in a certain locality might be identical with species of other areas, but they seldom had comparative material.

Beebe and Tee-Van (1936) found the taxonomy of the tuna and other mackerel-like fish in great confusion due to the inadequacy of early descriptions, definitions, and illustrations, to ignorance of the changes occurring during growth, as well as to the difficulty of preserving large specimens for detailed laboratory examination. They also found that many of the older descriptions are meager and lacking in necessary detail, making of the literature a mass of data that cannot be coordinated or correlated.

Jordan and Evermann (1926) wondered if the European tuna *(Thunnus thynnus)* and the two American forms *(Thunnus saliens* and *Thunnus secundodorsalis)* should not be considered only one form since their variations were probably due to defects of the illustrations (the descriptions in some cases were made from drawings or photographs) rather than to peculiarities of the fish.

Kishinouye (1923) was unable to tell whether the albacore of the Atlantic and Mediterranean *(Germo alalunga)* was identical with the Pacific form, because he had no specimens available for comparison.

There are many valid reasons for the lack of adequate comparisons of specimens of tunas from various parts of their distribution. Their large size makes it difficult to collect and store them in museums. The chubs, or Spanish mackerels, however, are not large fish, and they still have not been studied on a world-wide basis. Some authors recognize four species for the North Atlantic and North Pacific *(Scomber colias, Pneumatophorus grex, P. diego,* and *Scomber japonicus);* others, such as Jenkins (1925), listed one species *(Scomber colias)* for the same areas. Fraser-Brunner (1950) recognized one species *(Scomber japonicus)* for all the oceans and listed two subspecies *(Scomber japonicus japonicus* and *Scomber japonicus colias),* the first a southern subspecies, the second a northern one extending down, however, to Brazil and the Cape. For all the oceans, up to five or six species have been recognized by other authors.

Systematically, the pilchards or the "sardines of California" fare no better than the mackerels. Regan (1916) recognized only one species of pilchard *(Sardina sagax)* for Chile, Peru, and the Pacific coast of the United States, Lower California, Japan, and the Union of South Africa, and wrote as follows:

It is not improbable that a statistical study of a large series of specimens would lead to the definition of the Japanese (*S. melanosticta*), Californian (*S. caerulaea*), and South African (*S. ocellata*) pilchards as subspecies not fully identical with the typical (*S. sagax*) from Chile. The close relationship of this species to *S. pilchardus* is shown not only by the structure of the adult fish, but the eggs and larvae also are precisely similar (*fide* Kishinouye), and their growth, food, migrations, etc., are the same.

Although these species are small in size and support the largest commercial fisheries in the world, their relationship and validity are not yet clearly delineated.

AN INTERNATIONAL APPROACH TO TAXONOMY OF MARINE FISH

Fish have served as sources of sport and food for as long as man can remember. As the number of people has multiplied, so has the need for fish increased. To obtain more fish, the rowboat and sailboat have given way to efficient powered vessels, and the sounding lead has been replaced by the sonic depth finder. Thus, catching fish is fast becoming more of a science than an art.

Knowing the fish that he catches has intrigued man ever since he started fishing, but identifications and descriptions have traditionally been more of an art than a science. However, since the time of Linnaeus, the recognition and description of fish has become increasingly more scientific, although even today it is practiced in an amateurish way by a great host of anglers and fishermen and scientifically by an inadequate number of professionals. The trained investigators who describe, name, and classify fish, are here referred to as taxonomists and the corresponding discipline as taxonomy.

Taxonomists, when they began to work with marine fishes, did not have much help from other disciplines to supplement their studies: the concept of population was undeveloped; oceanography and ecology did not exist as separate disciplines; and the knowledge of the seas in general was very meager. The commercial fisheries were not as developed as they are now, which made it difficult to get large numbers of specimens from distant regions for detailed comparative studies, and to acquire better knowledge on the number, distribution, and relationship of the species. Consequently, early studies were not as complete as they can be today.

Hubbs (1943) said that marine fishes and other groups of vertebrates may seem to exhibit sharp distinctions between species and other taxonomic categories, only because the systematic studies have been based on fewer specimens or have been less analytical, or because the systematic picture has been more dominated by convention and "authority." He suspected that the truth involved both alternatives.

Today taxonomy is evolving toward the development of broader approaches for the study of marine fish. Some taxonomists are trying to put together and analyze, on a world basis, the geographically more restricted studies of their predecessors; but they are able to do so only when they have access to large numbers of specimens collected throughout the ranges of the animals concerned. As examples, we have the papers published by Fraser-Brunner (1950), Godsil and Holmberg (1950), and Schaefer and Walford (1950).

The world revision of tunas and mackerels of Fraser-Brunner (1950) is a valuable contribution to the understanding of these fish on a world basis, and he is right in stating that some confusion has been caused by workers who refuse to believe that the fish occurring on their particular piece of coast can possibly be the same species as that from some other part of the world. The studies of Godsil and Holmberg on bluefin tunas, genus *Thunnus*, and of Schaefer and Walford on yellowfin tunas, genus *Neothunnus*, show that a great deal more intensive analytical study of the species of tuna from different parts of the world is necessary before a thorough knowledge of the tuna relationships will be acquired.

Godsil and Holmberg made an extensive comparative study of the anatomy and morphology of six specimens of American Atlantic bluefin tuna, six specimens of the Australian southern bluefin tuna, and a large number of specimens of American Pacific bluefin tuna. They also made a general comparison among all the varieties of bluefin tuna of the world. Although the authors arrived at some conclusions on the relationship of the species of bluefin tuna, they concluded that a discussion or revision of the nomenclature of the species of the genus *Thunnus* was premature.

Schaefer and Walford made a detailed comparative and statistical analysis of large samples of yellowfin tunas from Angola, Africa, and from the Pacific coast of Central America. They found that more information regarding variability of tuna populations within oceans compared with variability between oceans is necessary before a better understanding of the yellowfin tunas of the world is acquired.

These two last studies were made possible by international cooperation, and they show that for a continuous production of valuable revisions and studies of marine fish of the world, an international approach has to be developed.

Taking as an example the international approach given to fishery problems by some fishery biologists or scientists, the usefulness of international cooperation will, I believe, be well illustrated.

With the increased amount and intensification of fishing, many fish stocks have become exhausted and a few scientists, mostly biologists, have applied themselves to the investigation of the causes of depletion. A discipline, which has loosely been called "fishery biology," "fishery research," or "fishery science," developed from their studies, which had rational fishery management as the ultimate purpose. This discipline is here referred to as fishery science or fishery biology; its practitioners as fishery scientists or fishery biologists. These men study the dynamics of fish populations, whole populations with a view to relationships, distribution, life history, migrations, ecology, and behavior; conduct detailed studies on random samples collected at several geographic locations; and perform statistical analyses of the samples to detect the similarities and differences in a large group of individuals, with a view to guiding the orderly exploitation of fishery resources. In some instances, in order to learn the divisions and relationships of separate stocks or races within a population, they also use the same morphological characters (such as meristic characters or body proportions) that are employed in taxonomic procedures.

Some fishery scientists are realizing that in many cases only a cooperative international investigation will permit them to study a species of fish effectively. As an example of the methods used and of an international approach can be cited the work done by the International Fisheries Commission.

The International Fisheries Commission, during its study of the Pacific halibut *(Hippoglossus stenolepis)*, conducted growth studies and racial investigations with specimens collected throughout the whole area of distribution which includes the coasts of the United States, Canada, and Alaska, to determine the existence of independent stocks or populations. It was found that the halibut of the northern banks had a larger head and slower growth than the halibut of the southern banks. Migration studies carried on by tagging a large number of specimens throughout the distribution showed that very limited intermingling of adult fish occurred between the northern and southern banks. But for all practical purposes, the entire stock was found to consist of two separate populations of the same species.

Thus it seems that through international cooperation this investigation, by comparing samples from the whole range of the species, established the existence of intraspecfic stocks, gave a precise picture of the distribution of the species, but did not result in the multiplication of species.

NATURAL BARRIERS AND ZOOGEOGRAPHICAL REGIONS

Natural barriers are limiting factors in the distribution of some groups of fish, but are of less consequence to other groups. For example, the distribution of the oceanic bonito *(Katsuwonus pelamis)* circumscribes the globe, in waters ranging from 20° C. to 6° C. It is possible that within this worldwide population there may exist different units or subpopulations, but to date they have not been found sufficiently independent to be considered distinct species by taxonomists.

A similar situation exists with regard to the distribution of sardines, of which Myers (1940) said:

> Actually, to a fishery researcher in the midst of a great faunal zone, the boundaries of that zone become important only when the species with which

> he is concerned ranges to its borders, or beyond. A good example is the California sardine, or pilchard (*Sardinops*). These sardines occur not only along the temperate North American coast but also in the temperate Asiatic, Australian, South American, and South African faunas. Dr. Walford and I are unable to tell apart specimens from any of these five regions save the Australian. Australian examples seem to differ slightly but constantly, and form one species *S. neopilchardus*, while all the others seem to be referable to *S. sagax*. Depletion of the California supply and attendant conservation efforts make it extremely important to know whether the four great populations of *S. sagax* can have any communication across sharp faunal boundaries. If they can, the drain on one population might be relieved by migration or infiltration from distant sources.
>
> Speaking as one who is not a sardine biologist but who has gone rather extensively into faunal distribution, I believe it extremely unlikely that a surface-swimming, semipelagic fish inhabiting as cool water as does this sardine, could pass the equatorial regions, and I think that the southern temperate *Sardinops* never have communication with the northern populations. On the other hand, the Japanese and California populations are in the same fish fauna, and I believe that there may be sporadic if not extensive intermingling in the North Pacific.

In discussing pelagic species in general, Myers (1940) said:

> Something must be said of the pelagic species such as the tunas and swordfishes. I have already mentioned that they do not obey the distributional laws of shore fishes, and at least some of the species appear to migrate through areas of very different temperature conditions. With the tunas and swordfishes, this apparent indifference to temperature changes that are barriers to other fishes may have some relation to the fact that they are warm-blooded creatures, maintaining a body temperature often as high as 10° F. above that of the surrounding water. No one knows their life histories; they come, stay awhile, and are gone. Their spawning places are a mystery, and young examples, at least of the tunas, are practically unknown. The adults are usually too big to permit museum examination and we do not know yet whether the species of Japan are the same as those of California, or whether either are the same as those of Oceania. At first sight, it seems that most of the species have enormous ranges or annual migrations, but recent chemical studies of the liver oils tend to show that the Japanese and American forms of some species may be distinct. I am inclined to think that both the Japanese and the West American tunas spawn in tropical Oceania and I have one report of ripe individuals in eastern Polynesia. Perhaps, if the American and Asiatic species are distinct, both spawn in the same general area, like the Atlantic eels. What appear to be the same species are common in New Zealand and Australian waters and I have no doubt they are to be found off Chile, where few have fished for them.

I have found that the bluefin tuna is recorded as *Thunnus thynnus* along the coast of Europe and West Africa, *Thunnus secundodorsalis* on the Atlantic coast of the United States, *Thunnus thynnus* again on the Pacific coast of the United States, and *Thunnus orientalis* on the coast of Japan. This is a typical example of the results of taxonomic studies based on specimens from only one locality, instead of comparison of samples from throughout the distribution of the fish.

TAXONOMIC INVESTIGATIONS OF LARGE AREAS OF THE WORLD

There has been in recent years a decrease in the number of taxonomic studies covering large areas of the world. For instance, the "Check List of the Fishes and Fishlike Vertebrates of North and Middle America

North of the Northern Boundary of Venezuela and Colombia" (Jordan, Evermann and Clark, 1930), the most recent study dealing with that entire area, was published 20 years ago, and no effort has since been made to bring it up to date. The American Fisheries Society recently published "A List of Common and Scientific Names of the Better Known Fishes of the United States and Canada" (1948). This work covers more than five hundred species of fishes, but it was not designed as a substitute for a "Check List."

The study now started by the Sears Foundation for Marine Research, "Fishes of the Western North Atlantic," is a great contribution toward the understanding of the fishes found in the area between Hudson Bay and the Amazon River including the outer borders and the opposite side of the Atlantic. Works of this scope when carried out in other sections would undoubtedly clarify the understanding of the marine fishes of the world.

Twenty or thirty years ago, there were more ichthyologists actively engaged in the study of fish taxonomy than now. A recent rapid calculation made with Dr. Leonard P. Schultz, Curator of Fishes of the United States National Museum, showed not more than a dozen taxonomists active in fulltime taxonomic work in North, Central, and South America combined. Such small effort cannot be expected to contribute effectively to the development of investigations over larger areas of the oceans, the study of larger areas, and to the building of an international approach to the study of marine fishes.

Conclusions

The apparent arrested development of taxonomic work on tunas, mackerel, sardines, and other groups of fish is due principally, in my opinion, to the following reasons:

1. There were in the near past great schools of taxonomists like the one created and led by David Starr Jordan in the United States and that in the British Museum in England. These schools no longer exist in their past strength. There is an apparent reduction in inspiration and leadership in accelerating and enlarging the development and production of fish taxonomy.

2. This reduction in the number of significant groups of workers and leaders deprives the field of the strength required for the acquisition of better financial support. This support is essential to enable the field to maintain the pace of related fields, such as fishery science and the fishery industry.

3. The lack of large groups of workers and means for the development of their activities reduces the field to limited scattered works. The deficiencies also delay the development of new broad approaches, for example complete studies of large samples taken from different

geographic areas of the distribution of a species. This would require from the taxonomists not only national but also broad international cooperation, since studies of international scope have been proved to be of paramount importance in the study of the oceans and their living organisms. Several international organizations have been considering broad international taxonomic works as one of their primary problems. The Conseil Permanent International pour l'Exploration de la Mer invested a great amount of time and money in the arrangement of the *Faune Ichthyologique de l'Atlantique Nord,* which is a systematic study of the common and commercially important fish of all northern Europe, made possible through the cooperation of several taxonomists from different countries. A similar study was started in the Mediterranean Sea by the Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranee in its *Faune et Flore de la Mediterranee.* Now the Indo-Pacific Fisheries Council, sponsored by the Food and Agriculture Organization, has included in its program of work the taxonomic studies of fishes of the Indo-Pacific regions, in cooperation with the taxonomists of this vast area.

Myers (1940) stated:

> It is clear that a great many species of marine fishes, perhaps the majority, have "international" ranges and that perhaps the majority of commercially important species transcend the sea-ward jurisdiction of nations, whether it be the "three-mile limit" erroneously supposed to be fixed by international law or any other artificial limit.

If fish have international habits, their study requires an international approach which can be fulfilled only by large groups of taxonomists working in close international cooperation.

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THE DETERMINATION OF AGE AND RATE OF GROWTH FROM VERTEBRAE OF THE CHANNEL CATFISH, *ICTALURUS LACUSTRIS PUNCTATUS*[1]

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ABSTRACT

Age and rate-of-growth calculations were made from the fifth vertebrae of 535 channel catfish *(Ictalurus lacustris punctatus)* taken from Pool 9 of the upper Mississippi River at Lansing, Iowa. Vertebrae were collected during the summers of 1945 and 1946 and examined with the aid of a standard scale projector. They were prepared by removal of adhering material with a solution of pepsin and hydrochloric acid. Direct observation of the centra of the vertebrae revealed annular rings which were shown to be true year marks when checked by the usual tests of validity. In addition field samples were compared to fish of known age. Body-vertebra relationship was shown to be curvilinear and appropriate corrections were made in all calculations. Growth of catfish is slow throughout life and progresses at a uniform rate for a longer period than is characteristic of most fresh-water fishes. Growth is greatest during the second year of life and Lee's phenomenon is not apparent in calculations based on older fish. Growth increment in succeeding calendar years varied greatly but trends showed a striking resemblance to those of fresh-water drum taken from the same water during the same period. Body length-weight relation is expressed by a parabola with the formula $\log W = -4.2738 + 3.66 \log L$. A few catfish mature at a length of 12 inches but 100 percent of the fish are not mature until a length of 22 inches is attained. Sex ratio was 1.12 males to one female.

INTRODUCTION

The channel catfish *(Ictalurus lacustris punctatus)* is an important sport and commercial species in many areas of the United States, especially in the waters of the Mississippi River system. Its management requires detailed knowledge of life history including rate of growth and age-class structure in normal populations. Although techniques of age and rate-of-growth determination have been well worked out in species of scaled fish, adequate methods for similar analysis in the catfish have not been available. The present study was an attempt to validate the use of vertebrae for this purpose, and to describe growth phenomena of the Mississippi River channel catfish. Vertebrae were selected because they could be secured easily from fish caught in the commercial fishery, and they appeared to have growth structures which could be readily interpreted.

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Data for this investigation were collected during the summers of 1945 and 1946 under the auspices of the Upper Mississippi River Conservation Committee with the cooperation of the Iowa Conservation Department and the Fishery Research Unit of the Minnesota Department of Conservation. All vertebrae were collected from fish caught within the limits of navigation pool No. 9 of the Upper Mississippi River Lock and Dam System in the vicinity of Lansing, Iowa.

Although various bony structures have been used to determine age of fish for more than 50 years (Reibisch, 1899), Heincke (1904) was one of the earliest workers to age fish successfully from the vertebrae. Many investigators who followed Heincke utilized vertebrae and other bony structures for aging of fish. Their work has been well summarized by Menon (1950). Lewis (1949) studied the age and growth of *Ameiurus* spp. in Iowa waters from their vertebral markings. Hooper (1949) assumed that vertebrae could be used for age determination of *Schilbeodes mollis*. Sneed (1951) has recently used pectoral spines for age determination of channel catfish.

METHODS OF INVESTIGATION

Collection of Material.—Vertebrae were collected at different times throughout the summers of 1945 and 1946 from commercial fish brought into the Lansing Fish Market at Lansing, Iowa. Fish smaller than the legal limit of 12 inches were also brought in by special arrangement with commercial fishermen. In 1946 fish taken by a field crew of the Upper Mississippi River Conservation Committee were added to those taken from other sources. The fish examined were taken with seines, trot lines, bait nets, and box traps.

The fifth vertebra was selected for study because it showed all essential markings and could be taken easily from the fish. In the commercial dressing of catfish the head is broken from the body in a manner which leaves the spinal column complete. Since the first four vertebrae are fused, it is comparatively easy to cut the ribs attached to the fifth and separate it from the others. Vertebrae collected in this manner were placed in coin envelopes upon which was noted the locality and date of capture, kind of gear employed, sex, stage of gonad development, total length in inches, and weight in pounds.

Preparation of vertebrae.—In order to determine age and rate of growth from the centra of the vertebrae, it was necessary to emphasize the year marks and project them with suitable magnification onto a screen. Various methods of sectioning were tried, but proved to be impractical. Direct observation of growth rings from the face of the centrum was then attempted and proved to be a workable method.

Several means of removing the tissue which adhered to the centra were explored. The method finally adopted for general use was digestion with a solution of 0.7 percent pepsin in 0.2 percent hydrochloric acid. Each vertebra was placed in a numbered vial containing 10 milliliters of digestive solution, and incubated at 100° F. for 24 hours. This treatment cleaned the bones without appreciably softening their surface or obscuring the growth marks.

Designation of growth marks. — A vertebra which is satisfactorily cleaned shows wide light-colored bands alternating with narrower dark bands. The dark bands are interpreted as year marks and the wider, light-colored bands are considered to represent annual growth increment. Some vertebrae, however, have dark bands which cannot be interpreted as true year marks. A true year mark consists of a complete dark ring concentric with the rim of the vertebra. This ring may vary in width from little more than a line to what could properly be called a zone, and is usually accompanied by a ridge on the surface of the centrum. A false year mark is incomplete, terminates in the lateral fields, or is indistinct.

Examination of prepared vertebrae.—The number of annuli on vertebrae was determined with the aid of a low-power dissecting microscope having 7x magnification. Measurements of vertebrae were made with the aid of a scale projector which was modified to project the reflected image of the centrum on a viewing screen. Vertebrae were held by means of a two-pronged wire clamp in such a manner that they could be rotated to bring the ventral field of the centrum into focus from its center to its edge. Measurements were made by placing a millimeter rule along the ventral radius of the projected image and recording the distances from the center of the centrum to each annular ring.

DETERMINATION OF AGE

Determination of age and rate of growth of catfish from vertebrae depends upon the correlation of growth marks with passage of time and increased body size. In order to establish the fact that the annular marks were true year marks the data calculated from the assessed age and vertebral measurements of 535 fish were checked in several ways. If age assessment was correct: (1) there should be agreement between the modes of length-frequency distribution of all fish in the sample with modal lengths of fish assigned to each age group; (2) the length of young fish calculated from the vertebrae of older fish should agree with empirical length of young fish of the same assigned age at the time of capture; (3) calculated growth histories of fish collected in different calendar years from the same population should be the same within the range of sampling error; (4) strength or weakness of individual year classes should persist in collections of successive years; and (5) age assessed from vertebral marks on captive fish must correspond to their known age.

Comparison of modes of length-frequency distribution with mode of distribution in each age group.—Comparison of peaks in the length-frequency polygon of the entire sample with modes of length frequency in each assigned age group shows considerable agreement especially in the younger age class (Figure 1, Table 1). The range of size in each age group particularly in later years of life results in enough overlap

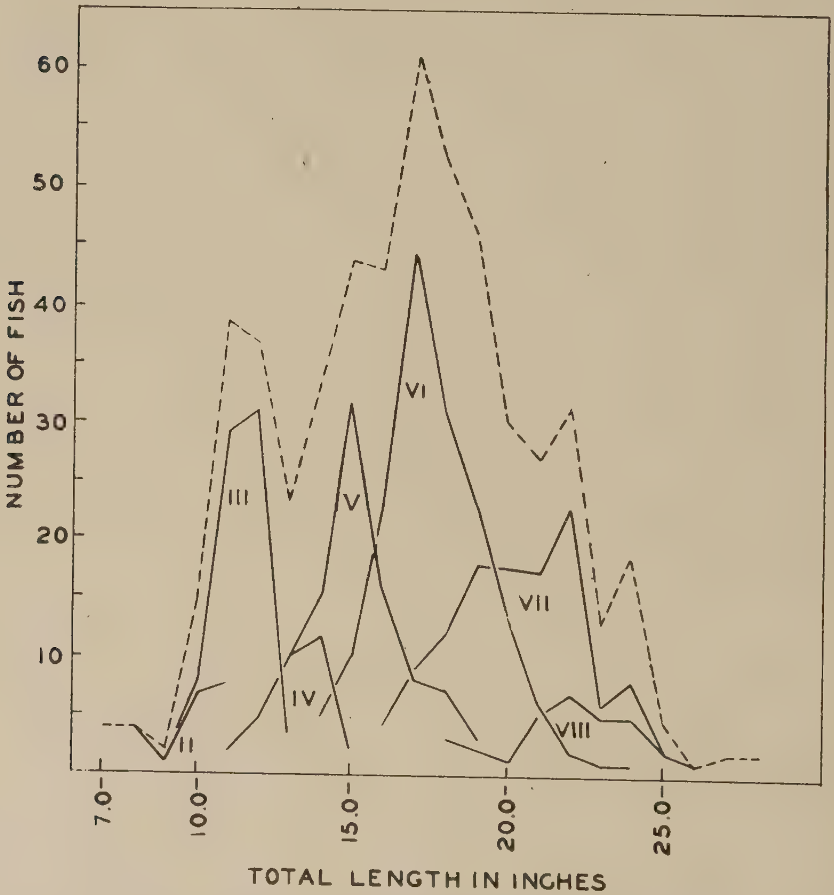

FIGURE 1.—Length frequency of sample of channel catfish (broken line) collected from the upper Mississippi River (1945-1946) compared with length frequencies of fish assigned to each age group (solid lines). Roman numerals indicate successive age classes.

TABLE 2.—*Grand average calculated lengths at the end of each year of life of all age groups of channel catfish of both sexes taken in 1945 and 1946 at Lansing, Iowa.*

Age group	Number of specimens	Average length at capture	Year of life											
			1	2	3	4	5	6	7	8	9	10	11	12
I	0	....	....	....	....	....	....	....	....	....	....	....	....	....
II	24	9.83	2.96	7.23	....	....	....	....	....	....	....	....	....	....
III	73	11.72	2.70	6.97	9.83	....	....	....	....	....	....	....	....	....
IV	32	13.70	2.86	6.23	9.05	11.72	....	....	....	....	....	....	....	....
V	92	15.71	2.94	6.11	8.76	11.33	13.75	....	....	....	....	....	....	....
VI	160	18.05	3.02	6.12	9.08	11.64	14.07	16.34	....	....	....	....	....	....
VII	115	20.96	3.01	6.26	9.00	12.01	14.59	17.04	19.17	....	....	....	....	....
VIII	28	22.31	3.10	6.35	9.22	11.76	14.27	16.36	18.83	20.84	....	....	....	....
IX	7	24.93	3.26	6.32	9.39	12.22	15.44	17.68	19.54	21.65	23.80	....	....	....
X	1	28.00	2.83	3.94	8.98	12.48	15.89	18.62	21.09	23.93	26.12	27.46	....	....
XI	2	26.20	2.65	5.46	7.16	9.77	12.94	15.67	18.30	20.19	22.55	24.08	25.08	....
XII	1	28.30	3.01	6.29	9.37	13.10	16.71	20.12	22.82	24.93	25.81	26.76	27.67	27.97
Average calculated length	....	....	2.95	6.33	9.11	11.69	14.16	16.64	19.15	21.14	23.97	26.60	25.94	27.97
Number of specimens	535	....	535	535	511	438	406	314	154	39	11	4	3	1

TABLE 1.—*Number of fish in each age group (sexes combined) of channel catfish taken from Pool No. 9, Upper Mississippi River, during the summers of 1945 and 1946—expressed by 1-inch intervals.*

Total length in inches	Age group											
	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
28—28.9	...	...	...	...	...	...	...	...	1	...	1	2
27—27.9	...	...	...	...	...	1	...	...	...	1	...	2
26—26.9	...	...	...	...	...	...	...	1	...	...	...	1
25—25.9	...	...	...	...	...	2	2	1	...	...	...	5
24—24.9	...	...	...	...	1	8	5	4	...	1	...	19
23—23.9	...	...	...	...	1	6	5	1	...	...	...	13
22—22.9	...	...	...	...	2	23	7	...	...	...	...	32
21—21.9	...	...	...	...	6	16	5	...	...	...	...	27
20—20.9	...	...	...	...	12	17	1	...	...	...	...	30
19—19.9	...	...	...	3	23	18	2	...	...	...	...	46
18—18.9	...	...	...	7	31	12	3	...	...	...	...	53
17—17.9	...	...	...	8	45	9	...	...	...	...	...	62
16—16.9	...	...	...	16	23	4	...	...	...	...	...	43
15—15.9	...	...	2	32	10	...	...	...	...	...	...	44
14—14.9	...	...	13	16	5	...	...	...	...	...	...	34
13—13.9	...	3	10	10	...	...	...	...	...	...	...	23
12—12.9	...	31	5	...	1	...	...	...	...	...	...	37
11—11.9	8	29	2	...	...	...	...	...	...	...	...	39
10—10.9	7	8	...	...	...	...	...	...	...	...	...	15
9—9.9	1	1	...	...	...	...	...	...	...	...	...	2
8—8.9	4	...	...	...	...	...	...	...	...	...	...	4
7—7.9	4	...	...	...	...	...	...	...	...	...	...	4
Number of fish	24	72	32	92	160	116	30	7	1	2	1	537

TABLE 3.—*Empirical and calculated lengths of catfish collected from pool 9 of the upper Mississippi River in 1945 and 1946—each year's data calculated separately.*

Age group	1945 Collection			1946 Collection		
	Number fish	Length at capture	Calculated length[1]	Number fish	Length at capture	Calculated length[1]
1	0	....	2.96	0	....	2.96
2	0	....	6.09	24	9.84	6.52
3	2	12.95	8.94	71	11.73	9.35
4	17	14.03	11.50	15	13.33	11.92
5	67	15.74	13.98	25	15.63	14.41
6	120	18.00	16.43	40	18.20	16.89
7	20	19.59	18.37	95	21.26	19.22
8	4	20.93	21.06	24	22.54	21.12
9	1	25.90	24.84	6	24.77	23.78
10	0	....	26.76	1	28.00	25.20
11	0	....	27.67	2	26.20	25.08
12	1	28.30	27.97	0	....	....
Total	232	....	....	303	....	....

[1] Grand average calculated from all fish in the single year's collection.

TABLE 4.—*Number of fish in succeeding year classes from 1933 to 1944 collected in the calendar years 1945 and 1946.*

Years collected	Year class											
	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
1945	1	0	0	1	4	20	120	67	17	2	0	0
1946	0	0	2	1	6	24	95	40	25	15	71	24

between groups to mask to some extent the coincidence of the modes, but agreement is good enough to give support to the vertebral method of aging fish.

Comparison of calculated lengths with empirical lengths.—Comparisons between calculated lengths at any annulus and empirical lengths for fish of that age at time of capture show good agreement (Table 2). As would be expected, agreement is not exact since fish taken during the growing season will be longer than their length at the time of the formation of the last annulus.

Comparison of growth histories of fish collected in different calendar years.—The growth histories of 232 fish taken in 1945 agree closely with the histories of 303 fish taken in 1946 from the same population. Such agreement would be expected if the criteria used to assess age are suitable. In each sample there is close agreement between average empirical lengths of corresponding age groups (Table 3). The calculated lengths of separate age groups of one sample also compare closely with those of the other sample except in fish over 9 years old where numbers are small. Empirical lengths for the third and fourth years of life taken in 1945 are well above those of the same ages taken in 1946. It is believed that this discrepancy is caused by some selectivity in the sampling for 1945. In this year fish came entirely from the commercial catch, while those taken in 1946 included fish below legal size. The legal commercial catch, which includes only fish above 12 inches total length, will contain the fastest growing catfish of the younger age groups. From the fifth to eighth year of life the discrepancies are not considered to be significant.

Persistence of strong year classes.—Persistence of strong or weak year classes in the collections of different years is good evidence of accuracy in age assessment. In the 1945 collection, the largest portion of fish taken was of the 1939 year class, which was then 6 years of age. In the 1946 collections, this year class still predominated, and was now 7 years old (Table 4).

Comparison of wild population with fish of known age.—In the fall of 1945 a sample of young-of-the-year channel catfish was seined from the Mississippi River and placed in one of the U. S. Fish and Wildlife Service ponds at Fairport, Iowa. In the autumns of 1946, 1947, and

1948 samples[2] of these fish were taken and their vertebrae checked. Since growth of these fish was much better than that of wild fish, no direct comparison of growth of known-age fish and wild fish can be made. However, considerable verification of the general method was secured from these samples. First, the number of rings formed on the vertebrae corresponded in all cases to the known age of the fish. Further, calculated growth histories from these fish agree very well with empirical data from the younger groups of known age (Table 5).

The evidence from the various checks presented above appears to justify the use of annular rings on vertebrae of channel catfish to assess age even though some specimens are obscure and must be discarded. Additional verification of a more circumstantial nature is suggested in the section dealing with growth in different calendar years.

BODY-VERTEBRA RELATIONSHIP

Calculation of growth history of a fish from measurements of a skeletal part depends upon the establishment of a definite relationship between growth of the part and growth of the entire body. In the present study the size of the fifth vertebra was compared to the body length of the fish throughout the range of sizes represented in the entire sample. When the data were grouped by 10-millimeter intervals of vertebral radius and a rectilinear regression line calculated, the fit with the empirical lengths was good in fishes above 10 inches but unsatisfactory for fish below that length. In addition the regression line intersected the base line at a point representing a fish length of 2 inches. A second degree parabola with a general formula of

$$L = a + bx \mp cx^2$$

seemed to describe the true relationship more closely.

Adaptation of the general formula by solving for the constants *a*, *b*, and *c* resulted in the following formula which described body-vertebra relationship:

$$L = 0.639793 + 0.262434r - 0.000537\, r^2$$

where *L* equals total length in inches and *r* equals the ventral radius of the vertebra in millimeters times 18.[3]

TABLE 5.—*Calculated length at the time of each annulus formation of fish of known age collected in 1946, 1947, and 1948 at Fairport, Iowa.*

Year collected	Age group	Number	Length at capture	Calculated length at each annulus		
				1	2	3
1948	III	38	18.62	2.09	8.98	15.56
1947	II	19	15.85	2.06	8.93	....
1946	I	19	9.39	2.11	....	....
1945	0[1]	....	....	....	....	....

[1] Between 2 and 3 inches at time of planting in pond.

---

[2] The number of vertebrae collected each year is as follows: 1946 — 20; 1947 — 20; 1948 — 38.

[3] Vertebrae were magnified 18 times by the scale projector.

A comparison of the calculated curve with empirical data (Figure 2) indicates that the curve fits the data satisfactorily except in a few instances. At the lower end of the size range (between 8 and 12 inches total length) the empirical points fall well below the curve. These points are represented by smaller fish which come into the commercial catch. Since all types of gear are selective of certain size groups, it is assumed that these fish had grown faster in length than was normal, and that ossification about the rims of their vertebrae had not yet

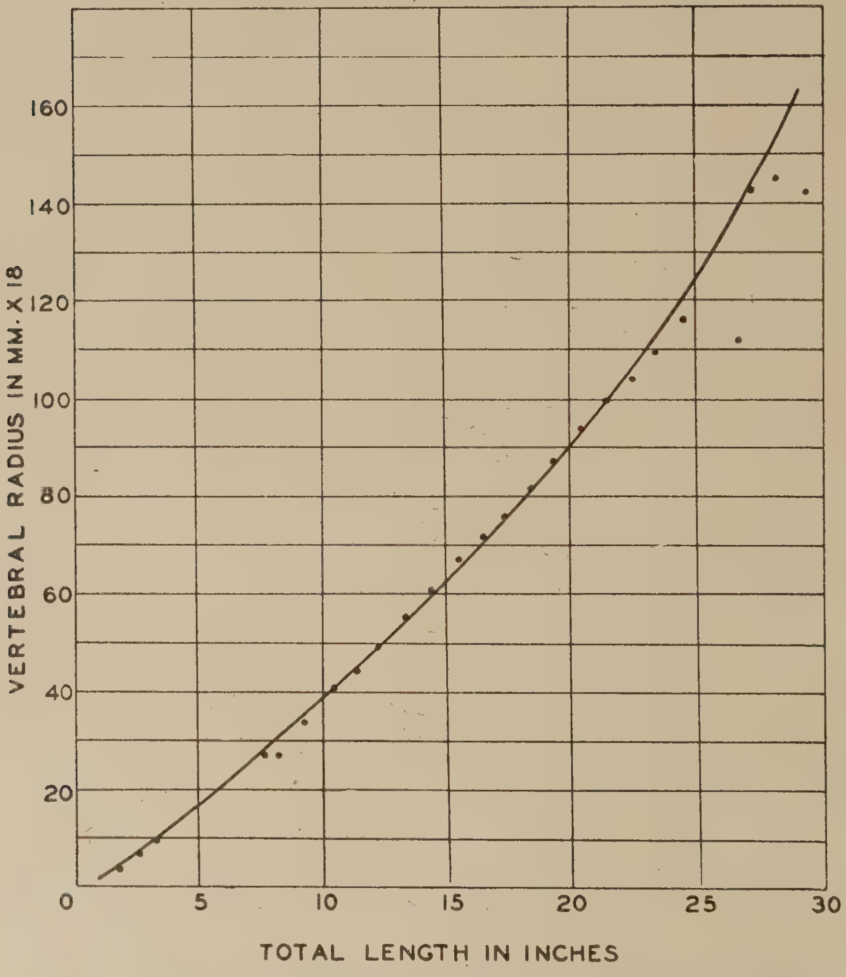

FIGURE 2.—Body-vertebra relationship of Mississippi River channel catfish collected in 1945 and 1946.

taken place. Cleaning the vertebrae removed this material, and only the measurement of ossified bone was recorded. There would be a tendency, therefore, for fast-growing fish taken during the early part of the season to be longer than their vertebral radii would indicate. Yasuda (1940) showed that annular rings on the centrum were formed about 1½ months later than on the otolith in *Scombrops* sp. Discrepancies along the upper portions of the curve are believed to reflect the influence of smaller samples of large fish.

It might be expected that when a fish is at its shortest length it would have a vertebra of a measurable radius. It appears that this is not exactly true, however, since the curve will intersect the base line at the value of the first constant in the above formula, namely 0.639793 inches total length. It is felt that late ossification of the vertebrae may cause this phenomenon since some workers have found that complete ossification of all vertebrae may not be attained simultaneously. The particular vertebra used in this study, therefore, may have formed sometime after ossification began, and after the fish had attained some length. To calculate true lengths from measurements of the vertebrae a table was prepared by solving the above formula for each one-half millimeter increase of vertebral radius and used in the manner of Hile (1941).

Growth histories of seven age groups of male channel catfish caught during the summer of 1946 were calculated on a straight line and curvilinear basis. A comparison of the results indicated that a high degree of error would result from calculation of length on a direct proportion basis. In most instances uncorrected values were too small.

RATE OF GROWTH

Average calculated lengths at successive annuli.—Calculated lengths of both sexes in both years' collections have been combined for general discussion of growth. Although there appeared to be some differences in average calculated lengths of male and female catfish, these differences were not significant when given the *t*-test. Lengths and increments in Tables 2 and 6 respectively are grand average lengths and grand average increments calculated from all age groups. However, since older age groups are represented by very few fish, data from them is not considered to be representative.

Increment in length was greater during the second year of life than in any other year. Investigations on many species of fish have shown that growth in the first year of life is often the greatest, and that the increment lessens in each succeeding year. The present divergence from this type of growth is caused by the relatively late hatching time. Young fish, starting their second year of life, have a growing period at least 1 month longer than young-of-the-year fish with the result that the increment for the second year of life is greater. After the second

TABLE 6.—*Grand average increments in length of channel catfish of both sexes taken in 1945 and 1946 at Lansing, Iowa.*

Age group	Number of specimens	Year of life											
		1	2	3	4	5	6	7	8	9	10	11	12
I	0	....	....	....	....	....	....	....	....	....	....	....	....
II	24	2.97	3.84	....	....	....	....	....	....	....	....	....	....
III	73	2.72	4.24	2.82	....	....	....	....	....	....	....	....	....
IV	32	2.86	3.37	2.82	2.56	....	....	....	....	....	....	....	....
V	92	2.94	3.16	2.65	2.57	2.42	....	....	....	....	....	....	....
VI	160	3.08	3.10	2.96	2.56	2.43	2.27	....	....	....	....	....	....
VII	115	3.01	3.24	2.97	2.78	2.58	2.45	2.16	....	....	....	....	....
VIII	28	3.10	3.25	2.87	2.54	2.51	2.45	2.08	2.08	....	....	....	....
IX	7	3.06	3.07	3.40	2.65	2.25	1.86	2.11	2.14	....	....	....	....
X	1	2.83	1.11	5.04	3.50	3.41	2.73	2.47	2.84	2.19	1.34	....	....
XI	2	2.65	2.81	1.70	2.61	3.17	2.73	2.63	1.89	2.36	1.53	1.00	....
XII	1	3.01	3.28	3.08	3.73	3.61	3.41	2.70	2.11	0.88	0.95	0.91	0.30
Average increment	....	2.97	3.37	2.84	2.63	2.49	2.36	2.14	2.09	2.07	1.44	0.97	0.30
Number of specimens	535	535	535	511	438	406	314	154	39	11	4	3	1

growing season, increments decrease slowly and steadily (Figure 3). Although small numbers of fish in the older age groups tend to make the growth curve irregular from the eighth year of life onward, the downward trend is clearly evident. Growth of catfish is slow throughout the life period, but continues at a more or less even rate for a longer time than in many other fishes. There is little evidence that Lee's phenomenon of apparent change in rate of growth is present in channel catfish.

Range of length in the age groups.—There is a high degree of overlap in lengths between age groups and some indication that the range in length within the different age groups increases with an increase in age (Table 1). Fishes longer than 10 inches may belong to three or four different age groups. The large range in fish of the same age

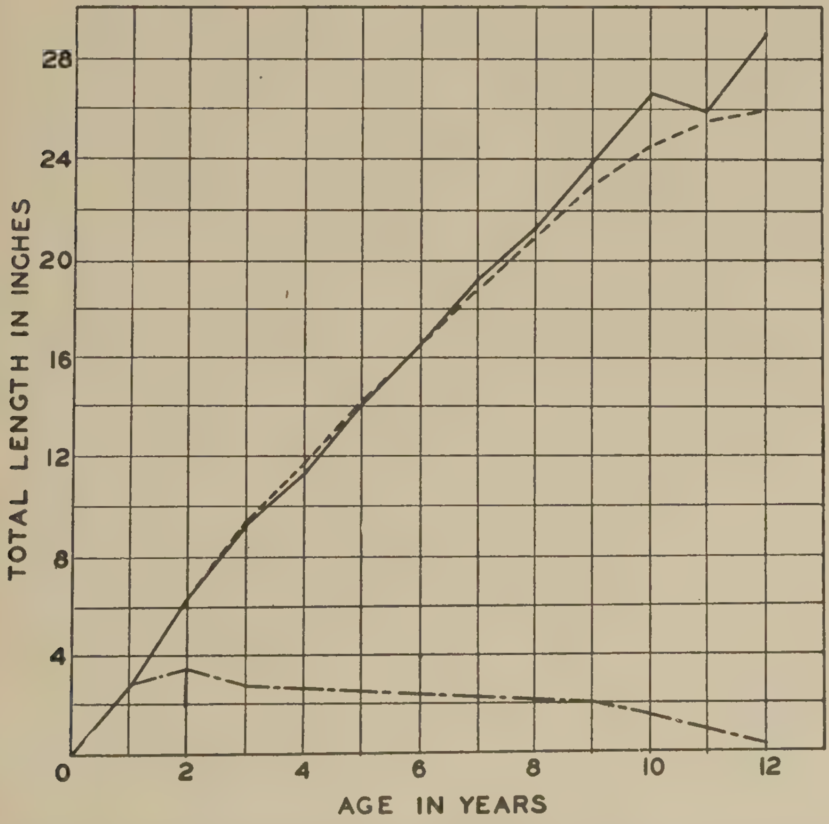

FIGURE 3.—Calculated length at each annulus (solid line), annual increments (dots-dashes), and summation of annual increments (broken line) in channel catfish from the Mississippi River.

TABLE 7.—*Percentage deviation from mean annual increment in length of channel catfish and fresh-water drum taken from the upper Mississippi River—1945-1946.*

Year of collection	Species	Calendar Year							
		1938	1939	1940	1941	1942	1943	1944	1945
1945	Catfish	—1.4	+7.4	—3.4	+1.5	—2.5	—3.0	....	....
1946	Catfish	....	—2.6	—4.5	—0.1	+0.5	—0.3	+3.3	+0.9
1946 and 1948	Drum (Butler & Smith, 1950)	....	+7.8	+1.5	+4.4	—4.7	—1.6	+3.5	—7.3

group is not believed to be indicative of an error in the method of age determination. In catfish of known age held in a pond at Fairport, Iowa, one-, two-, and three-annulus fish had a range in length of 3.1 inches, 4.8 inches, and 5.9 inches, respectively.

Variation in growth during succeeding calendar years.—It is apparent from examination of the data that there is considerable variation in the annual growth increment in succeeding calendar years. A measure of this difference can be secured by calculating the percentage variation of each year's growth from the mean annual increment during the period of observation (Hile, 1941). In the present instance deviations for each calendar year were calculated separately for both the 1945 and 1946 samples. All ages and year classes, including the eighth year, were included in the calculation with the exception that the growth in the first year of life was omitted.

When percentage deviations from the mean of the 1938-1943 annual increments were calculated on the basis of the 1945 collection, the trends from year to year were, with the exception of 1942, the same as those resulting from similar calculations based on the mean of the 1939-1945 increments determined from the 1946 samples (Table 7). The discrepancy noted is believed to have resulted from the use of small numbers of fish representing the 1942 growth in the 1945 collections. Butler and Smith (1950) made similar calculations from their data on the growth of the fresh-water drum collected in the Mississippi River. There is a high degree of agreement between the trends of their fluctuations and those demonstrated for the catfish. Although the causes of annual fluctuations have not been assessed, agreement of the calculations for two species from the same area strongly suggest that the calculated variations provide a reliable index of general growth conditions within the habitat. The agreement between data calculated from catfish collected in two different years also provides a verification of the accuracy of age determination from vertebrae.

Growth increment within a single season.—An approximation of the growth attained during succeeding periods of the growing season may be obtained by comparing growth increment for that part of the growing season preceding capture with the increment for the entire season as calculated from samples of the same year class taken in the subsequent calendar year. The method employed is as follows:

Fish taken in 1945 were collected on June 21 and 29, and August 17 and 22. The difference between the last calculated length and the length at time of capture was obtained for each fish in the 1945 collections. For each of the two periods, June and August, the average difference, or the growth to the time of capture was determined for each age group. This average was divided by the increment for that year and calculated from fish of the 1946 collections. This quotient was multiplied by 100 to obtain the percentage of growth attained at time of capture (Table 8).

TABLE 8.—*Comparison of calculated growth in inches to time of capture of four age groups of channel catfish in 1945 with the growth for the entire season as calculated from fish taken in 1946 collections of the same year class—number of specimens indicated in parentheses.*

Age group	1945 growth to time of capture		Total 1945 growth computed from 1946 collections	Percentage of year's growth completed at time of capture	
	June	August		June	August
IV	2.21 (2)	2.09 (14)	2.26 (25)	97.8	92.5
V	1.95 (22)	1.97 (38)	2.05 (40)	95.1	95.6
VI	1.29 (35)	1.94 (79)	2.16 (95)	59.7	89.8
VII	0.66 (7)	1.14 (12)	2.05 (24)	32.2	56.1

The percentage of growth completed at time of capture varied considerably between the four age groups under consideration. Some of the variation is probably caused by small sample size in some of the age groups, especially age groups IV and VII. A tendency does appear, however, for younger fish to grow more rapidly during the early part of the growing season and have the major portion of their annual increment attained by midsummer. Older fish appear to grow more slowly and more continuously throughout the growing season.

GROWTH IN WEIGHT

Length-weight relationship.—Data for determination of length-weight relationship of channel catfish were obtained by combining both sexes of fish in both years' collections in order to obtain as large a sample as possible in each size group (Table 9). It is believed that combination of the sexes will not appreciably influence length-weight relationship, and for most practical purposes is satisfactory. Calculation of constants and the expression of variables in logarithmic form resulted in the equation:

$$\log W = -4.2738 + 3.66 \log L$$

where W = weight in pounds and L = length in inches.

Comparison of actual and calculated weights (Table 9 and Figure 4) shows that the equation fits the empirical data reasonably well. The greatest differences between actual weights and calculated weights are encountered in larger fish and are probably caused by the small number of these fish. In fish sizes where numbers in each size group are large, differences are limited to a few hundredths of a pound. The value of the exponent shows that the weight of channel catfish increases to a power much greater than the cube of the length and thus indicates that the body shape changes rapidly as fish grow in length.

REPRODUCTION

In the vicinity of Lansing, Iowa, channel catfish spawn about the middle of June although they may spawn as early as May or as late as July. In general spawning occurs whenever the water reaches a temperature of approximately 75° F. Canfield (1947) reported that the number of eggs varied with the size of the fish, but that the number of eggs ranged from about 1,500 to 2,000 per pound of body weight. He also observed that catfish held in ponds did not produce eggs until the fourth year of life. Of 456 catfish examined during the summers of 1945 and 1946 no fish in their first 4 years of life were regarded as being mature (Table 10). In the fifth year of life 17.6 percent of both

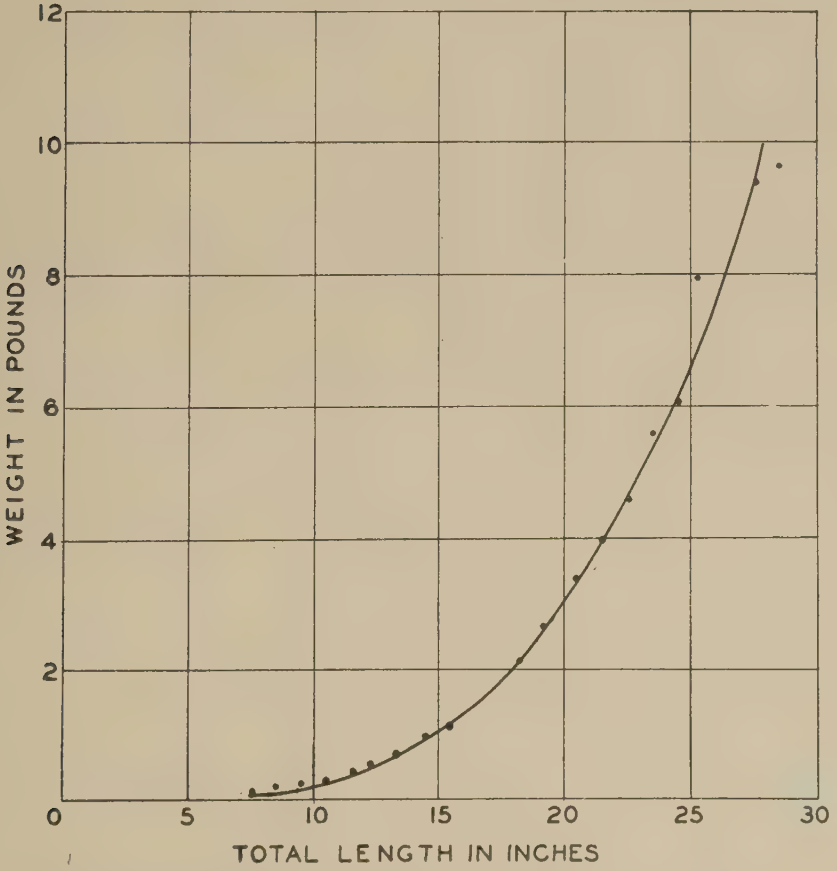

FIGURE 4.—Length-weight relationship of Mississippi River channel catfish collected in 1945 and 1946.

TABLE 9.—*Data employed in determination of length-weight relationship of channel catfish of both sexes and taken during the summers of 1945 and 1946.*

Size interval (inches)	Number of fish	Average total length (inches)	Average weight (pounds)	Calculated weight (pounds)
28.0—28.9	3	28.47	9.51	11.21
27.0—27.9	3	27.33	9.35	9.65
26.0—26.9	....	....	....	....
25.0—25.9	6	25.25	7.91	7.25
24.0—24.9	21	24.33	6.04	6.29
23.0—23.9	15	23.50	5.49	5.55
22.0—22.9	38	22.56	4.77	4.78
21.0—21.9	31	21.49	3.90	4.00
20.0—20.9	38	20.51	3.33	3.37
19.0—19.9	50	19.25	2.63	2.67
18.0—18.9	60	18.29	2.17	2.22
17.0—17.9	75	17.27	1.81	1.80
16.0—16.9	55	16.65	1.61	1.53
15.0—15.9	53	15.43	1.16	1.19
14.0—14.9	38	14.57	0.97	0.97
13.0—13.9	29	13.35	0.65	0.70
12.0—12.9	51	12.29	0.56	0.52
11.0—11.9	53	11.45	0.42	0.41
10.0—10.9	18	10.39	0.30	0.27
9.0— 9.9	7	9.43	0.24	0.20
8.0— 8.9	9	8.48	0.18	0.13
7.0— 7.9	4	7.68	0.12	0.11

sexes showed some degree of sexual development. Beginning with the sixth year a large percentage of both sexes was mature. At the beginning of the ninth year of life 100 percent of the males and 90 percent of the females were mature.

Neither sex reaches maturity below a length of 12 inches, but many in the 13-inch group are mature (Table 10). In the 15-inch group more than half of both sexes are mature, and as the fish grow larger, the number of individuals attaining maturity increases gradually.

As they increase in length the percentage of fish attaining sexual maturity increases until 100 percent are mature at a length of 22 inches.

TABLE 10.—*Percentage of mature channel catfish at each succeeding 1-inch interval from 11.1 to 26 inches.*

Total length in inches	Male	Female	Sexes combined
11.1-12	0.0	0.0	0.0
12.1-13	4.0	0.0	2.0
13.1-14	64.3	33.4	50.0
14.1-15	50.0	35.7	43.3
15.1-16	58.4	66.7	62.6
16.1-17	....	....	....
17.1-18	74.0	74.2	74.1
18.1-19	82.5	86.4	84.5
19.1-20	88.5	87.5	88.0
20.1-21	66.7	63.6	65.2
21.1-22	90.0	72.7	81.4
22.1-23	100.0	100.0	100.0
23.1-24	100.0	100.0	100.0
24.1-25	90.0[1]	100.0	95.0
25.1-26	66.6	....	....

[1] Sterile or senile.

TABLE 11.—*Percentage of sexually mature male and female channel catfish in each age group taken at Lansing, Iowa—summers of 1945 and 1946.*

Sex	Age group							
	I	II	III	IV	V	VI	VII	VIII
Male	....	0.0	0.0	17.6	66.7	74.4	84.9	100.0
Female	....	0.0	0.0	17.6	73.7	73.6	81.6	90.0

TABLE 12.—*Sex ratios of channel catfish taken in different types of gear.*

Type of gear	Percentage of total take	Ratio males per female
Box trap	45.21	1.85
Bait net	2.97	1.25
Seine	10.56	1.13
Trot line	8.91	0.77
Wing net	17.49	0.66
Frame net	2.64	0.60
Buffalo net	3.96	0.33
Trammel net	1.32	0.33

Beyond a length of 24 inches the percentage of male fish which appear to be sexually mature decreases. This condition suggests the possibility of senility.

Sex ratio.—As in the case with most nest-building fishes, sex ratios of channel catfish are approximately equal. From a sample of 304 catfish it was determined that 53 percent were males while 47 percent were females or a ratio of 1.12 males per female (Table 11). Because nearly half (Table 12) of this sample was obtained through the use of box traps in which female catfish were used as bait for male fish, it was felt that the sample might not be representative of the sex ratio existing in the population. This disproportionate catch by box traps did not appear to affect greatly the average sex ratio as determined by fish taken in all types of gear. Examination of a sample of 373 catfish taken entirely by seining at Bay City, Wisconsin, in 1946 showed a sex ratio of 1.13 males per female. Since seines used were large and covered a wide area it is reasonable to assume that this latter sample would show the sex ratio existing in the population. On this basis it is felt that a ratio of 1.12 males per female is a normal condition existing in the catfish population at Lansing, Iowa.

CONCLUSIONS

Application of age and rate-of-growth data to fishery management problems has its limitations and reaches its maximum usefulness only when combined with data on mortality and replacement. If subsequent investigations into the life history and management of channel catfish reveal that a more adequate spawning stock is necessary to maintain the fishery, such an increase could be effected by raising minimum size limits. The present minimum size limit of 12 inches total length permits taking of female fish before they have reached maturity. A 14-inch minimum size limit would allow about one-third of the females to reach maturity before entering the fishery. It appears from the available data that box traps are highly selective of males but that larger proportions of females are taken by other common types of gear. The net result in the vicinity of Lansing, Iowa, is to catch both sexes in proportion to their abundance.

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HORSE LIVER AS THE CAUSATIVE FACTOR IN WHITE BLINDNESS OF HATCHERY BROOK TROUT[1]

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ABSTRACT

White blindness, a dietary disease peculiar to brook trout, was previously reported by the author as having appeared in the early spring of each year from 1946 through 1949 at certain fish hatcheries throughout Michigan. Brown and rainbow trout were not affected by the disease. White blindness is characterized by a very pale body color, and a milky opaqueness of the crystalline lens of the eyes which renders the fish blind. Analysis of the diets at hatcheries where the malady appeared, and where it was absent, strongly suggested that horse products were the cause of it, but the diversity of products included in the diets made it impossible to determine whether one or all horse products were involved. The present experiments were conducted in an effort to determine which horse product was responsible for producing white blindness.

Cooked horse skeletal muscle, horse hearts, and horse livers each mixed with pork melts on a 50-50 basis were tested. Brewer's yeast at a 5 percent level was added to the diet of one group of fish receiving each diet.

White blindness was first observed on December 19, 1949, among the group of brook trout fed the horse liver-pork melt diet continuously since June, 1949, and increased in incidence until the experiment was terminated on May 3, 1950. No symptoms of the disease were present among trout fed any other diet in the experiment.

Results of this experiment indicate that horse livers may safely comprise up to 50 percent of the diet of brook trout during summer months but will cause white blindness when used at that level during prolonged periods of low water temperatures.

INTRODUCTION

White blindness, a dietary disease peculiar to brook trout and characterized by opaque crystalline lens and pale body color (Figure 1), appeared at various trout stations in Michigan in the early spring of each year from 1946 to 1949. Since trout commonly change to a dark body color when they become blind, the unusual pale body color of the blind fish in this case leads to the name of "white blindness" for the disease.

The initial study (Allison, 1950)[2] presented an analysis of the diets used at stations where the disease was present and where it was absent (Table 1). This study demonstrated that the malady was caused by a diet which included 27.2 percent, or more, of horse products fed during winter months when water temperatures dropped below 40° F., and was absent where 18.2 percent, or less, horse products were fed. Brown and rainbow trout were not affected. Hess (1937) produced dietary blindness in rainbow trout by feeding an exclusive diet of pork spleen. However, the fish in his experiment changed to a darker body color as they became blind.

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[1] **Contribution from the Michigan Institute for Fisheries Research.**

[2] Published only as abstract.

The present study was undertaken to determine whether any single horse product might cause the disease, because the great diversity of diets employed by the various trout stations made it impossible to ascertain from the diet analyses which product was responsible. Since it was necessary to pursue the experiments at hatcheries under full production schedules, it was not feasible to make all the tests that might have been desirable. Therefore, experiments were designed to reveal only which horse product was responsible for the disease.

METHODS

Horse hearts, livers, and cooked skeletal muscle were investigated. These products were fed at 40 percent and 50 percent levels, which were well above the critical level as determined by the initial study (1949). The experiment extended from June, 1949, to May, 1950, a period of time that encompassed both summer and winter conditions. Cooked skeletal muscle was tested at the Baldwin station (Lake County) on 9,000 fingerling brook trout held in the same pond where white blindness had developed during each of the previous three winters.

At the Marquette station (Marquette County) 114,500 fingerling brook trout were divided into four groups. Group A was composed of 62,000 fish divided among eight ponds and was fed a diet consisting of equal portions of horse hearts and pork melts; Group B, with 17,000 fish in two ponds, received the same diet as Group A, plus 5 percent

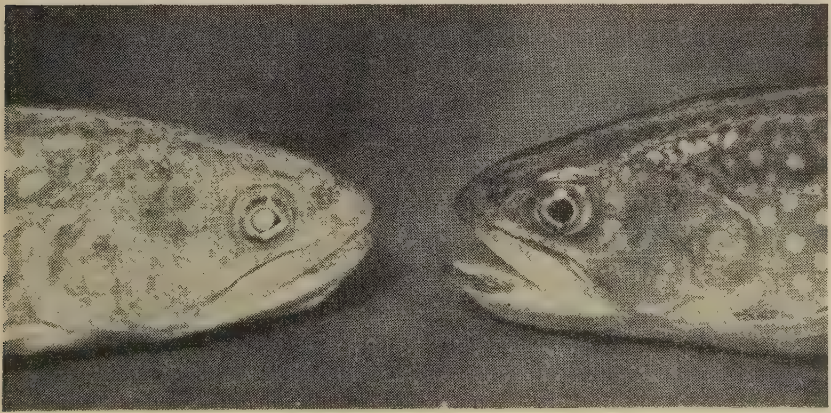

FIGURE 1.—Brook trout on left affected with white blindness; normal trout on right. Photo of live fish.

TABLE 1.—*Percentage composition of total diet at Michigan trout hatcheries, September, 1947, to June, 1948.*

Diet	Watersmeet[1]	Thompson[1]	Harrietta[1]	Wolf Lake[1]	Grayling[1]	Cooks Run	Oden
Horse liver	27.2	45.2	41.5	90.5	34.7	18.2	8.7
Horse heart		22.8	17.5		30.8		
Canned, cooked horse skeletal muscle			6.7	9.5			4.4
Horse skeletal muscle			2.7				
Pork liver	24.5					30.0	
Pork melts	34.6	25.9			30.0	39.7	36.6
Beef melts	13.3					4.4	
Beef liver					2.0		
Telang liver			6.4				
Cereal	2.3	6.0	24.7			7.1	33.6
Ocean herring			0.4		2.5		
Inedible beef liver							16.5
Total percentage horse products	27.2	68.0	68.4	100.0	65.5	18.2	13.1
Total percentage pork	59.1	25.9			30.0	69.7	36.6
Total percentage horse and pork	86.3	93.9			95.5	87.9	49.7

[1] Blindness present.

brewer's yeast (Strain K-2 Dried Brewer's yeast, Anheuser-Busch, Inc.); Group C, with 16,000 fish in two ponds, received a diet consisting of equal portions of horse livers and pork melts, plus 5 percent brewer's yeast; Group D, with 19,000 fish in two ponds, received the same diet as Group C, minus the yeast. The ponds (Figure 2) were approximately of equal dimensions and were supplied individually with water from the same source.

Approximately 2 weeks after the first case of white blindness was observed by the hatchery superintendent at Marquette, a schedule was set up for examining the eyes of the fish every 2 weeks until termination of the experiment. The first check was made on 400 specimens from each group, the second check on 500 specimens, and all following checks, except the final one, were made on 600 specimens from each group. The final examination was made on 61.6 percent of groups C and D, in which white blindness had appeared. Since no affected fish were found in any of the routine examinations of Groups A and B, and none could be observed in these ponds at the time of the final check, individual examinations were not made on these fish. The pale skin of brook trout effected with white blindness renders them especially conspicuous in ponds having dark-colored bottoms, as is the case at the Marquette station.

Specimens for the routine examinations were collected by random sampling. At the time of collecting, all fish in a pond were confined to a small area at the lower end of the pond. They were thoroughly mixed and transferred a few at a time by scaps to 30-gallon tubs, carried into the hatchery building, and distributed into troughs for examination.

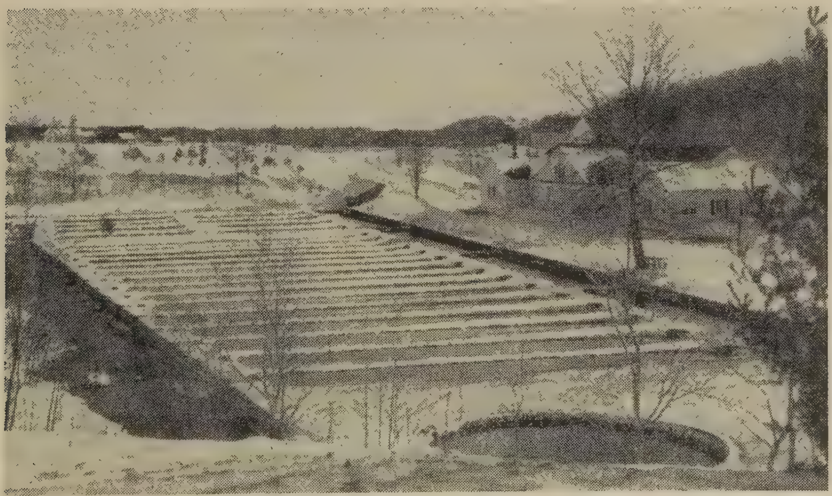

FIGURE 2.—Trout ponds at Marquette hatchery. March 29, 1950.

Each fish was held in the hands while both eyes were closely examined for any cloudiness of the crystalline lens. The degree of cloudiness, or opaqueness, varied from a thin milky color in one lens of some specimens to a dense, opaque whiteness in both lenses in other specimens. After the examinations were completed the fish were returned to their respective ponds.

At the Baldwin station, 9,000 yearling brook trout in one pond were fed from June, 1949, to April, 1950, on a diet consisting of 40 percent cooked horse skeletal muscle, 38 percent pork melts, 10 percent meat scraps, 10 percent skim milk powder, and 2 percent salt (NaCl). The pond chosen for this experiment was the same pond in which white blindness had appeared in the spring of the year in 1946, 1947, and 1948. No blindness was observed among the fish in this pond from the beginning of the experiment until the ice cover formed in late December. Five hundred fish collected by random sampling were examined on April 18, 1950, at which time the study was terminated at this station. The bottom of the pond was very dark in color, as at Marquette, and pale-colored trout were quite conspicuous.

RESULTS FROM THE DIETS

The first case of white blindness was observed by the hatchery superintendent at Marquette station on December 19, 1949, 7 months after initiation of the study, among fish of Group D, which received a diet consisting of 50 percent horse livers and 50 percent pork melts. Beginning on January 11, 1950, and every 2 weeks thereafter until May 3, 1950, routine examinations of all groups were made. The incidence of white blindness among fish in Group D gradually increased (Figure 3) during this period from 0.7 percent to 9.9 percent. In Group C, which received the same diet as Group D, plus brewer's yeast, the appearance of the disease was apparently delayed, but by May 3, 9.7 percent of the fish were affected. Thus, brewer's yeast did not prevent the appearance of the disease nor affect its intensity to any appreciable degree. There was no increase in loss among the groups of fish in which blindness developed. White blindness did not develop among the fish in either Group A or B.

At the Baldwin station, when ice cover melted and it was possible to observe the fish, no blindness was observed among the fish receiving a diet containing 40 percent cooked horse skeletal muscle. On April 18, 1950, after 10 months of the same diet, 500 fish were collected at random and examined for white blindness. No symptoms of the disease were found and the experiment was terminated at this station.

Of the three horse products tested (hearts, livers, and cooked skeletal muscle) only the livers were involved in the groups of fish contracting white blindness. The affected fish were fed this diet for 7 months before the disease appeared. It is beyond the scope of this study to point out

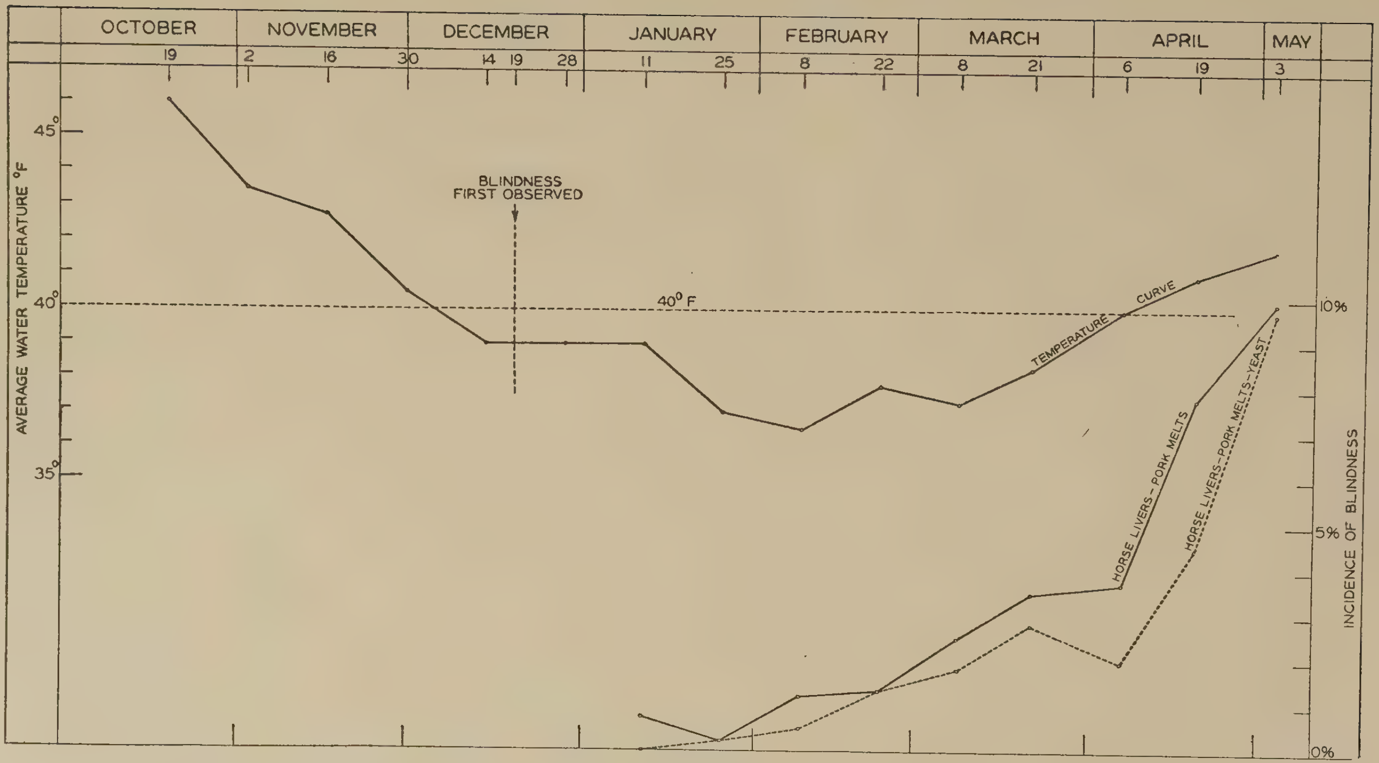

Figure 3.—Comparison of incidence of white blindness with water temperatures at Marquette Hatchery.

the specific agent responsible, whether length of time on the diet is important or whether low water temperatures are significant. However, the fact that white blindness develops in brook trout during periods of low water temperatures suggests some correlation. Average water temperatures for the Marquette station (Figure 3) were plotted from the routine hatchery records taken daily at 6:00 a.m., noon, and 6:00 p.m. The average was derived from the daily maximum and minimum readings. Comparing the graphs of temperature and incidence of the disease it can be seen that the disease did not appear before the water temperature dropped below about 40° F. It is not possible to determine the exact critical degree of temperature from the data at hand. During the period when water temperatures remained below 40° F., incidence of the disease gradually increased, and climbed rapidly when water temperatures increased and passed 40° F.

Damage to the crystalline lens appears to be permanent because no recovery was noted among affected brook trout retained for a year in hatchery ponds and fed a diet free of horse products.

Although brown and rainbow trout do not develop white blindness, there is some evidence that other species of fish are affected. Lake trout fingerlings held over winter at stations feeding horse liver became blind and pale in color. The following year at the same stations, fish of the same species and age were normal when horse liver was omitted from the diet. In a personal communication Mr. Harold Wasko, Aquarist at the Toledo Zoological Park, Toledo, Ohio, informed the writer that he had observed white blindness among orange-spotted sunfish, longear sunfish, green sunfish, smallmouth and largemouth bass, and yellow perch. The fish were fed twice each week, horse liver on Monday and fish on Friday. He noted that some groups gorged themselves on horse liver and ate sparingly of the fish, and pointed out that such fish were subject to white blindness. Since water temperatures varied between 70° F. and 80° F. throughout the year it would appear that length of time on the diet is important in this case and not low temperatures.

CONCLUSIONS

White blindness can be a serious hatchery disease because affected fish are blinded permanently and thus are of little value for stocking purposes.

Fingerling brook trout may be safely fed a diet containing up to 50 percent horse liver for 6 months when water temperatures exceed 40° F. There are some indications that water temperatures below 40° F. are correlated with the onset of the disease in brook trout.

Lake trout also appear to be affected similar to brook trout. Brown and rainbow trout are not affected by white blindness.

ACKNOWLEDGMENTS

The fine cooperation of District fisheries managers Clifford Long and Stanley Lievense, Mr. Don Gilbert, in charge of the Baldwin station, and especially of Mr. Russell Robertson, superintendent of the Marquette hatchery, and his crew, was largely responsible for the success of this study.

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PRODUCTION STATISTICS AND COSTS IN RELATION TO FISH HATCHERIES

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Abstract

Production statistics and costs in fish hatcheries vary greatly because methods of record-keeping are not uniform. A method of procedure is presented which covers expenditures, production data, and the itemizing of facilities which govern the productive capacity of a hatchery. Such data for an individual unit are discussed and the available facilities are described.

Expenditures and production for a period of 1 year are given in accompanying tables. Statistics are presented in tabular form on the cost of unit production (1 pound), on production in relation to flow, to volume, and to rate of change per hour. If comparable information is made available for other hatchery units, comparisons may be made which will result in better hatchery design and more efficient management.

For many years, there has been a great divergence of opinion as to the cost of producing trout. Fish-culturists realize that variation in costs can be attributed to many factors which vary widely in different hatcheries. However, the greatest cause for deviation is the lack of a standard method of keeping hatchery records which would ensure uniform production statistics and permit direct comparison of costs. This paper presents a procedure for keeping records so that the efficiency of individual trout hatcheries may be evaluated.

Three major items must be considered in order to arrive at an accurate cost figure which can be used in comparing the efficiency of hatcheries. These items are the total cost of operating the unit for a given period of time (1 year), the weight of trout produced during the same period, and essential information on the available facilities. The last item is especially important for analysis of the efficiency of the hatchery.

Government agencies as well as commercial fish hatcheries have methods of accounting to meet their individual needs in recording expenditures. It is possible to classify costs under four major headings: personal service, maintenance and operation, fish food, and interest on the investment. Commercial hatcheries must include taxes.

A procedure for determining the weight of trout produced has been established (Deuel, *et al.*, 1942). A simplified method covers the following items: an accurate inventory of the weight of fish and eggs on hand at the beginning and end of the period, and the weight of fish and eggs shipped out and received during the period. The sum of these

TABLE 1.—*Expenditures at a trout hatchery for period April 1, 1949 to March 31, 1950.*

Item	Cost	
Personal service		$21,176.27
Line item (foreman)	$ 3,714.00	
Permanent fish-hatchery helpers (7 men)	17,462.27	
Traveling expense		1,124.91
Automotive expense		851.53
Communications		257.91
Fuel, light, power, and water		974.71
Clothing and clothing materials		43.68
Household, laundry, and refrigerating supplies and expense		178.73
Laboratory supplies and expense		140.00
Farm and garden supplies and expense		127.09
Special supplies and expenses		214.15
Fish food, including transportation		20,753.51
Repairs:		
Contract work and services	$ 3.75	
Sand, cement, concrete blocks, etc.	35.20	
Paint and painting materials	379.99	
Lumber and wood products	364.83	
Iron and steel products	232.97	
Heating and ventilating fixtures	17.50	
Plumbing fixtures	12.15	
Electrical fixtures	28.27	
Other repair materials, supplies and expense	3.55	
		1,078.21
Equipment, replacements		700.00
Equipment, additional		433.62
		$48,054.32
Investments: property, buildings, pond, etc.	$75,000	
at 4 percent		3,000.00
		$51,054.32

items, inventory difference (gain or loss) and shipped and received (gain or loss), will give the production figure.

The function of a trout hatchery governs its design. A complete producing unit provides pond space suitable for maintenance of brood stock, rearing ponds for the production of yearlings and large fingerlings, raceways or rearing troughs for small fingerlings, and hatching troughs for developing eggs, fry, and advanced fry. The arrangement of the component parts has a great influence on the cost of operation, especially for labor.

The flow of water and its temperature as well as the available pond space are of the utmost importance in attaining maximum production. One particular hatchery has attained a yield of 48.5 pounds per gallon per minute flow and 2.25 pounds per cubic foot of water space (Kingsbury, 1950). These figures have been approximated in other hatcheries that have been redesigned to establish the flow and pond space in a proper relationship. There is little doubt that production on the gallon-per-minute-flow basis will be greatly increased in the future.

The presentation of data covering an individual trout hatchery for 1 year's operation will aid in clarifying the procedure for keeping hatchery production statistics and costs thus far discussed. The hatchery chosen as an example is considered to be a first-class production unit. The property has an area of 15.5 acres. There is an eight-room foreman's residence, with bath, near the hatchery site. Back of the residence is a one and one-half-story garage 34 by 44 feet in size. The two-story hatchery building (36 by 76 feet), as well as the combination food preparation, food storage, and refrigerator building (24 by 38 feet, one and one-half story), is located on one side of the lower series of ponds.

The water supply is from four sources, all of which originate on the property. The total average flow is 1,200 gallons per minute and the water temperature of the combined supply reaches a maximum of 54° F. in summer and a minimum of 43° F. in winter. The water sources afford ample opportunity for aeration. Oxygen content on the main supplies is 7.3 p.p.m., carbon-dioxide content averages 5.0 p.p.m., and the pH is 7.5.

There are 56 hatching troughs which are arranged on each side of the hatchery building, each trough having its individual inlet and outlet. At their normal operating level, the troughs have a combined water volume of 336 cubic feet. A battery of outside rearing troughs is located between the upper and lower rearing ponds. The 84 rearing troughs are supplied with water from a head trough, which has 42

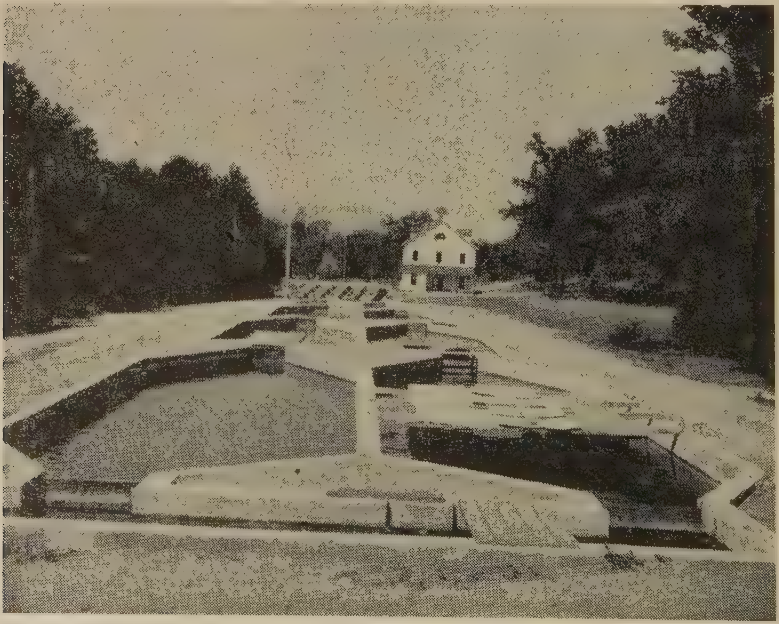

FIGURE 1.—Upper rearing ponds and rearing troughs.

TABLE 2.—*Detailed production data for a trout hatchery for period April 1, 1949 to March 31, 1950.*

Species	Shipped out		Shipped in		Length (inches)
	Number	Weight	Number	Weight	
Brown trout	1,869,396	365.37	4,074,321	789.69	eggs
Brown trout	103,032	216.0			1.75
Brown trout	236,076	8513.0			4.–4.75
Brown trout	54,024	3342.0			5.–6.75
Brown trout	218,885	31746.8			7. +
Brook trout	512,800	84.0	1,558,672	238.37	eggs
Brook trout	100,883	319.0			2.00
Brook trout	63,918	2662.8			4.–4.75
Brook trout	27,189	1517.0			5.–5.25
Brook trout	11,850	1755.0			7. +
Lake trout	1,297,092	342.53	2,555,998	668.23	eggs
Lake trout	459,420	5275.0			3.50
Lake trout	28,500	1441.0			5.75
Lake trout	46,564	3075.0			6.50

Shipped credit 58,958.21

Inventory
April 1, 1949 .... 13,840.0 pounds
March 31, 1950 .... 13,070.0 pounds
Inventory debit 700.0

Pounds produced 58,188.21

troughs on each side. Individual troughs are arranged in series of three. Waste water from the unit may be re-used in the lower set of rearing ponds or discharged directly into the adjacent brook. The 16 rearing ponds, which are identical in size and water capacity, each have a surface area of 648 square feet and at the normal operating level of 2 feet, a volume of 1,296 cubic feet of water. Half of these ponds are located above the rearing troughs and the other half below. They are normally serviced in series of four, but the design is such that any pond may be eliminated without affecting the operation of the others. A circular pond 50 feet in diameter is located at the lower end of the lower series of rearing ponds. It has a water capacity of 3,927 cubic feet when operated at the normal 2-foot level. The combined rearing space available at normal operating levels is 25,839 cubic feet. The general design of the fish-production units is shown in Figures 1 and 2.

All financial and production data relating to this hatchery are summarized in Tables 1 to 4. Table 1, which covers expenditures, is self-

TABLE 3.—*Production by quarterly periods for a trout hatchery for period April 1, 1949 to March 31, 1950.*

	1st quarter	2nd quarter	3rd quarter	4th quarter
Pounds	12,865	20,289	14,672	10,363
Percent	22.1	34.9	25.2	17.8

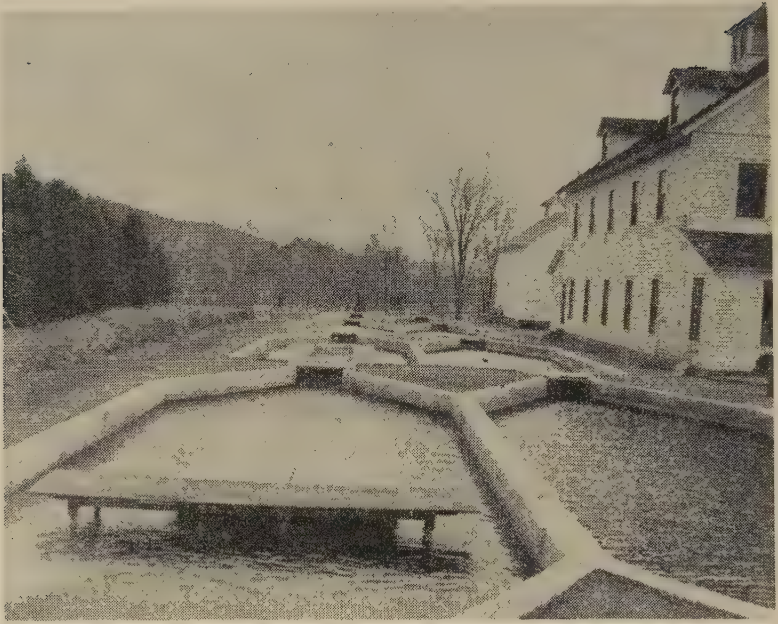

FIGURE 2.—Lower rearing ponds and hatchery buildings.

explanatory. Tables 2 and 3 give a summary of the hatchery's production including information as to the sizes of fish contributing to the production and a breakdown of the total by quarterly periods.

The first part of Table 4 presents the cost of the production on a unit basis of 1 pound for the three major items involved (personal service,

TABLE 4.—*Cost and production statistics for a trout hatchery for period April 1, 1949 to March 31, 1950.*

Item	
Personal service, cost per pound	$0.3639
Maintenance and operation, cost per pound	0.1053
Fish food, cost per pound	0.3567
Investment and interest, cost per pound	0.0515
Total cost per pound	$0.8774[1]
Pounds produced per gallon per minute flow	48.5
Pounds produced per cubic foot of space	2.25
Rate of change per hour,[2] total	0.37
Rate of change per hour, series of 4 ponds	0.46
Rate of change per hour, single pond	1.85
Rate of change per hour, series of 3 rearing troughs	5.33
Rate of change per hour, single rearing trough	16.0

[1] Does not include general administrative overhead.

[2] Rate of change per hour equals flow per hour in cubic feet divided by pond volume in cubic feet.

maintenance and operation, and fish food). The information contained in the second half of Table 4, taken together with the descriptive information on water supply and pond and trough areas, may be utilized in making comparison with production figures and costs for other hatcheries. Such comparisons can be made only if costs and statistics are available on a unit production basis as well as rates of change per hour (Phillip, *et al.*, 1947).

There is little doubt that such comparisons will lead to a better insight into the factors which determine efficiency in hatchery design and management.

ACKNOWLEDGMENTS

The hatchery that has been described has an excellent foreman in charge of operation who in turn has fine cooperation from his employees. Sincere thanks are tendered to the personnel who have aided greatly in furnishing data used in this presentation.

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EFFICIENCY OF FOOD CONVERSION BY YOUNG LARGEMOUTH BASS *MICROPTERUS SALMOIDES* (LACÉPÈDE)

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Abstract

The efficiency of food conversion by largemouth bass fingerlings was determined for a total of 138 individuals over a period of 6 years. The largemouth bass were kept in separate circular concrete pools 12 feet in diameter and 2 feet deep, and were fed small forage fish twice a week for periods varying in length from 5 to 12 weeks. The efficiency of food conversion was determined by dividing the weight of food consumed by the weight gained during the feeding period. Conversion factors varied from 1.5 to 24.2 the first year, but the variation was much less during the following 5 years. An average of about 4 pounds of forage fish was required to produce one pound of largemouth bass. Fingerlings less than 2 ounces in initial weight made more efficient gains than did those of 2 to 6 ounces in initial weight.

The quantity of food consumed by fish for maintenance and growth has interested fishery workers for many years and this subject has been studied by numerous workers. However, very little research has been conducted on the efficiency of food utilization by various species. This subject is of special interest in a consideration of supplemental feeding of hatchery-reared fish, and it is also important in the study of the relationships between forage fish and carnivorous fish in natural or artificial impoundments.

Thompson (1941) reported that 2.5 pounds of live minnows were required to produce 1 pound of largemouth bass, *Micropterus salmoides* (Lacépède), when fed at the optimum rate (3.5 to 4 percent of the body weight per day). His experiments were conducted in individual tanks at about 70° F. on about 20 largemouth bass ranging in size from large fingerlings to adult fish weighing 1 pound. He also stated that when larger amounts were fed the food was used less efficiently.

One of the objectives of the investigations conducted at the Alabama Agricultural Experiment Station was to produce by selective breeding a strain of largemouth bass that utilized food more efficiently and grew more rapidly than the one previously used in research at this Station. The experiments were conducted during the warmer months of the year when largemouth bass normally grow most rapidly (June-September). Those fingerlings (3 to 4 months old) that had grown most rapidly in rearing ponds were weighed accurately and placed in individual cir-

TABLE 1.—*Pounds of forage fish required to produce 1 pound of largemouth bass in feeding experiments carried on under hatchery conditions.*

Year	Length of feeding period (weeks)	Food	Number of bass	Pounds of food per pound of gain		Standard deviation of means
				Range	Mean	
1941	12	Goldfish	25	1.5—24.2	7.30	±1.12
1942	8	Bluegills	14	2.1— 6.0	3.09	±0.28
1943	5	Bluegills	24	3.0— 6.2	3.88	±0.16
1946	8	Fathead minnows	19	2.1— 9.0	5.12	±0.50
1947	7	Fathead minnows	27	1.1— 3.6	2.06	±0.15
1948	8	Fathead minnows	29	1.9— 8.7	3.44	±0.26

cular concrete pools 12 feet in diameter and 2 feet deep. Forage fish small enough for the bass to swallow easily were fed twice each week. The species used for food were goldfish, *Carassius auratus* (Linnaeus), bluegills, *Lepomis macrochirus* Rafinesque, and fathead minnows, *Pimephales promelas* Rafinesque.

During the first year of the experiment the bass were fed at rates varying from 0.5 to 9.5 percent of their initial body weight per day. Most of the individuals consumed all the forage fish given them. However, those fish which were fed at the highest rate sometimes did not consume all their food supply between feeding periods. Observation disclosed that occasionally a small fish died and was not eaten. For this reason the rate of feeding for all bass in the later experiments was 5 percent of the initial body weight per day, and all forage fish not eaten within 24 hours were removed. Accurate records were thus obtained on the weights of forage fish eaten by each individual bass. The efficiency of food conversion, or conversion factor, was determined by dividing the weight of food consumed by the weight gained during the feeding period. The most efficient individuals were selected as brood fish for the production of fingerlings to be used in feeding experiments the following year.

Data were collected during the years 1941, 1942, 1943, 1946, 1947, and 1948. The length of the feeding period each summer varied from 5 weeks in 1943 to 12 weeks in 1941, and the water temperature in the concrete pools varied from a minimum of 80° F. at night to a maximum of 90° F. during the day.

A summary of the pounds of forage fish required to produce 1 pound of largemouth bass is given in Table 1. During the first year there was a wide range in the efficiency with which the bass utilized food, since between 1.5 and 24.2 pounds of forage fish were required to produce 1 pound of largemouth bass. Great individual differences in efficiency of food conversion should be expected since the parents of the fingerlings were selected at random from a "wild" strain. Similar differences between individuals with respect to food utilization are apparently common among most animals. Although minor errors could be attributed to failure to remove uneaten fish at the end of 24 hours, the results indicated that the individuals tested varied greatly in ability to convert food into new flesh.

Further examination of the data in Table 1 reveals that, during the years 1942 and 1943, there was also considerable variation in efficiency of food conversion by individual bass, but the range in variation was much smaller than in the first year. In 1942 the range in conversion factors was 2.1-6.0, while in 1943 the range was 3.0-6.2. Apparently by the annual selection of the most efficient bass for brood stock some progress was made in obtaining a more efficient strain. It is believed that further progress would have been made had it been possible to determine the sex of those selected for brood fish. Then the two most

Table 2.—*Relationship between initial weight of bass fingerlings and pounds of forage required to produce 1 pound of bass.*

Initial weight ounces	Number of individuals	Average pounds of food required per pound of gain
0.0—1	29	2.24
1.1—2	18	2.68
2.1—3	28	4.03
3.1—4	15	4.33
4.1—5	11	4.40
5.1—6	8	4.15
6.1—7	1	3.50
7.1—8	2	4.40
8.1—9	1	3.90

efficient individuals of each sex would have sufficed, while actually 6 or 7 were always saved to make sure both sexes were present.

The feeding experiments were not continued during 1944 or 1945 and the efficient fish saved from the 1943 experiments were ultimately lost. Fish from the 1942 selected strain were used as brood fish to produce the fingerlings tested in 1946. The range in the conversion factors for that year was 2.1-9.0, which indicated that a larger number of less efficient fish was tested than during either 1942 or 1943.

The range in the conversion factors obtained in the 1947 experiments was 1.1-3.6 and the average for the 27 bass tested was 2.06. This average was the lowest obtained during any year; also the bass used in 1947 were smaller than in any other year. The relationship between initial size of bass and efficiency of food conversion is shown in Table 2, with the 1941 results omitted because they were thought to be less accurate than those obtained during the following years.

These data indicate that bass fingerlings with an initial weight of 2 ounces or less required an average of about 2.4 pounds of food to make 1 pound of gain, while fingerlings with an initial weight of from 2.1 to 6 ounces required an average of about 4.2 pounds. This was probably because the smaller bass required less food for maintenance and therefore utilized a greater percentage for growth than did the larger bass.

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MODIFICATION OF THE SEXUAL CYCLE IN BROOK TROUT *(SALVELINUS FONTINALIS)* BY CONTROL OF LIGHT

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Abstract

To facilitate handling of brook trout fingerlings during winter and to permit a shorter holding period for catchable-sized trout, experiments on shortening the sexual cycle by control of light were conducted on a commercial scale from 1939 to 1950. Light was increased over normal daylight and then decreased below normal daylight. This procedure caused fish to spawn as early as late July. Artificially lengthening the day in the fall retarded spawning. Early spawned eggs had a higher survival than normally spawned eggs and general hatchery efficiency was improved when early eggs were used.

Introduction

Brook trout *(Salvelinus fontinalis)* in the ponds of the American Fish Culture Company in Rhode Island normally are ready to spawn in late October or November. The stripping process often takes place during cold or stormy weather and the fry hatching out from the normally spawned eggs are not ready to start feeding until January. Most of the trout are sold alive for stocking of streams and lakes from March to June. There are, therefore, approximately 15 to 18 months from the first feeding to the second spring following the date of hatching. This period is too unseasonal and limited to produce fish large enough to satisfy the buyer of live trout so that these fish must be carried another full year to grow to a size suitable for the live trout demand. The great majority of the fry from normally produced spawn are held for a total period of 27 to 30 months. The disadvantage of this procedure is that it results in a longer period of feeding the fish and a much larger inventory to carry over. If some means of shortening this holding period could be devised a great increase in operating efficiency would result.

Response of Spawners to Altered Daylight

Promotion of early spawning would be one means of lessening the interval between hatching and delivery of trout to lakes and streams. That such a possibility existed was suggested by Hoover (1937). He succeeded in speeding up the sexual cycle by alteration of the amount of light on brood fish. His experiment was conducted in an aquarium and was begun February 20, 1937, with fish which were stripped on December 17, 1936. By using one 25-watt Mazda lamp and one 16-candle-power carbon filament to add up to 8 hours of light to natural sunlight and then inducing darkness until the equivalent of an 8-hour day was produced, Hoover succeeded in taking eggs August 31, 1937.

The original experiment conducted by the present authors began with the segregation in February, 1938, of 30 females and 15 males which had been spawned once previously. The fish used in all succeeding experiments and for production were also fish which had already spawned once. The schedule used by Hoover of increasing the light 1 hour a day the first week, 2 hours a day the second week et cetera until 8 hours more than natural sunlight had been reached, and then decreasing artificial light and finally sunlight at the same rate was employed.

The first eggs from this group of fish were taken on August 22 and all the fish were stripped by September 2, 1938. All eggs were hatched by October 12 and fry began to feed November 14. Both eggs and fry were satisfactory in every respect. Sample lots of these eggs were sent to five governmental agencies, State of West Virginia, Canadian Government, State of Michigan, State of New York, and State of Rhode Island, all of which reported satisfactory results.

An attempt was made to determine whether spawning could be delayed beyond the normal spawning period by lengthening the day

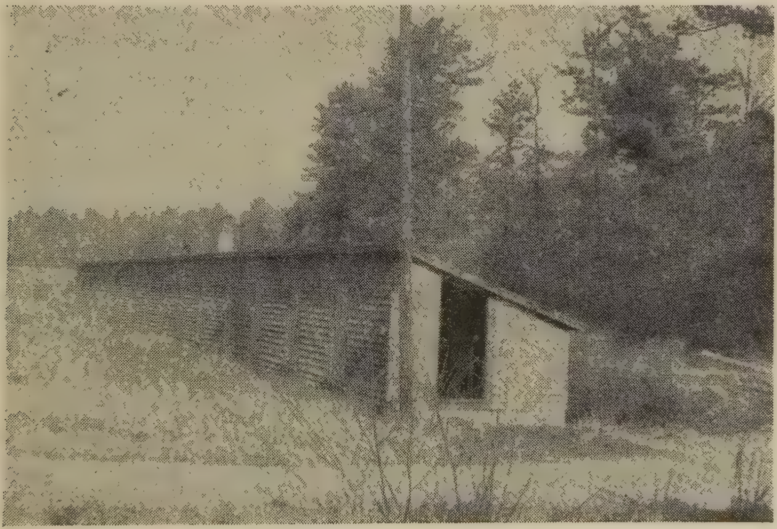

FIGURE 1.—Light-conditioning house for brook trout spawners.

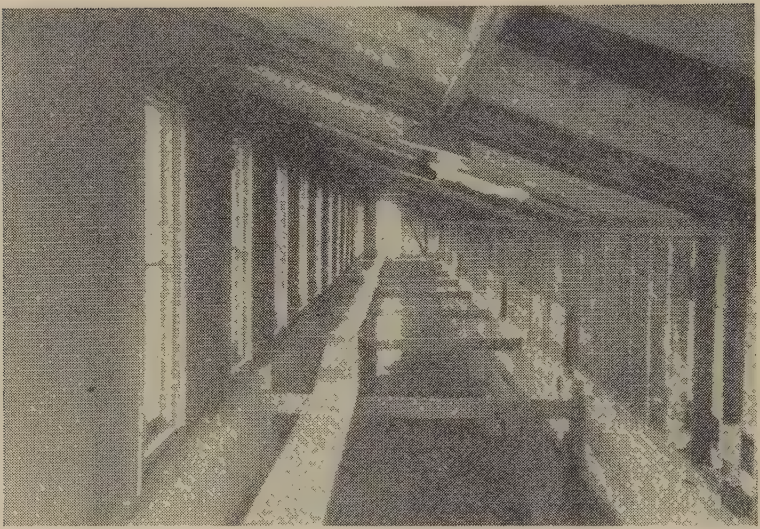

FIGURE 2.—Interior view of light-conditioning house showing lighting arrangement and interior shutters.

beyond normal daylight. This experiment was started on September 11, 1939, when the day was extended by adding 4 hours of artificial light. The first eggs in this experiment were taken December 12, 1939. Spawning had, therefore, been retarded approximately 6 weeks. Eggs from these fish were satisfactory in all respects.

Hoover states, "It is not known definitely from the completed experiments if it was necessary to add light to the brook trout to induce spawning or if merely diminishing the daylight period would have been sufficient." In order to ascertain whether both additional light and inducing darkness were required, a test was made in 1943 with 200 fish, using no additional light. The test was begun on August 1. Artificial darkness was induced for 1 hour each day for the first week, 2 hours for the second week, 3 hours for the third week, etc. The first spawn from this test were taken October 1, so that spawning had been hastened by 1 month. This experiment indicated that without the use of additional light, spawning was not advanced sufficiently to be of real value.

These results made it obvious that the spawning of brook trout could be advanced by first lengthening the day by the addition of artificial light and then by decreasing the length of normal day by inducing darkness. The company erected a building, constructed over a trout run, approximately 160 feet long by 10 feet wide (Figures 1 and 2). Windows were installed 10 feet apart on one side only and were

TABLE 1.—*Results of application of artificial light*[1] *to spawning brook trout from 1946 to 1950.*

Year	Number females	Date of spawning	Date of hatching
1946[2]	2,000	August 17	October 11
1947	1,980	July 21	September 14
1948	1,975	July 23	September 16
1949	1,925	July 28	September 21
1950	1,970	July 25	September 18

[1] Artificial light and then additional darkness was added as described in text.
[2] Artificial light not used until February 1.

equipped with inside swinging shutters. A string of 15 100-watt Mazda lamps, controlled by an automatic time switch, was installed over the run.

One hour of artificial light was given the first week of January, and 1 hour of artificial light was added each week until 9 hours of light above normal sunlight was produced. After the ninth week artificial light was reduced 1 hour weekly until actual daylight was reached. At this point artificial light was eliminated and 1 hour of artificial darkness (by shutting the shutters) was added each week until the fish spawned, which normally occurred the last week of July (Figure 3).

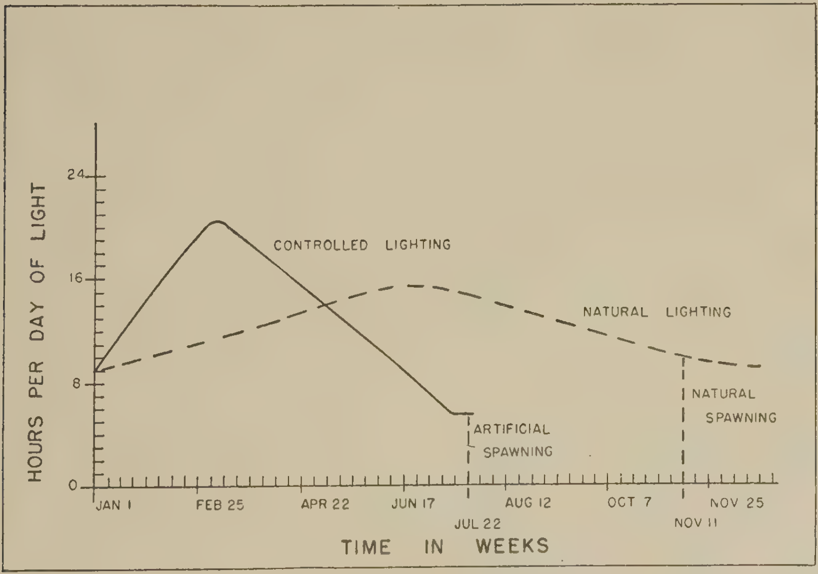

FIGURE 3.—Comparison of spawning time of brook trout accelerated by artificially controlled light with normal spawning time under natural light.

With the exception of the war years, this method has been used since the construction of the building in 1939 with substantially uniform results (Table 1).

RESULTS OF EARLY SPAWNING OPERATIONS

Many advantages of early spawning are immediately apparent. Early eggs can be taken during warm weather and placed in hatcheries when the water and air temperatures are favorable for quick hatching. Early hatching permits the fry to start feeding many weeks before winter weather produces low temperatures. In the New England states most hatcheries using early eggs produce fry which can safely be placed outdoors in small rearing pools before severe weather and thus eliminate over-crowding in the hatching houses during the winter. When eggs are hatched in September instead of December, the fry have approximately 19 months to grow before the planting season in the second spring following the date of hatching and in consequence most of them are large enough to be sold for stocking at that time. The carry-over of small fish into the third spring is thereby greatly reduced. Since many of the early trout are large enough to place outdoors in the winter months, the hatching houses are freed for use by the normally spawned eggs in December and January. This procedure allows hatcheries to be used twice in the same year.

In addition to these operating advantages there are several other features of the early spawning technique which improve hatchery results. The loss of spawners used in the early spawning is somewhat less and the eggs produced seem to be of higher quality. The fertility of eggs is greater, reducing the problem of picking, and the percentage of fry hatched is greater than in normally spawned eggs. Average survival of eggs placed in troughs is approximately 90 percent.

Disadvantages of the method are not serious but should be mentioned. Most important is the cost of construction and operation of the special holding-house for spawners. This expense substantially increases the cost of early eggs. Also, approximately 10 percent of spawners fail to respond to the light treatment. As would be expected, there is no genetic change in succeeding generations of early spawned stock so that light treatment must be maintained on a regular basis.

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THE GROWTH OF THE BURBOT *LOTA LOTA MACULOSA* (LeSUEUR) IN LAKE ERIE

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Abstract

Growth studies were made on 2,329 Lake Erie burbot collected from May to December, 1946. These data suggest that burbot show two types of growth which represent that of the immature and mature fish; that females become sexually mature at a length longer than males; that most burbot become sexually mature in their third and fourth years of life when they range from 340 to 440 millimeters in length. Incidental observations on spawning showed that in 1947, burbot in Lake Erie were spring spawners. Monthly observations throughout the entire course of a year indicated that the dark outer zone on the otoliths appeared in April and May shortly after spawning. Clear marginal zones were present for the remainder of the year.

Introduction

In Lake Erie, the burbot *(Lota lota maculosa)* is at present a non-commercial species of fish which often appears in such quantities in fishermen's nets that it is a nuisance. Many fishermen claim that these fish are detrimental but limited information has prevented an evaluation of the burbot's relation to other fish in Lake Erie. A growth and food study was started in May, 1946, and continued throughout the entire year. The rate-of-growth study is presented here.

Investigations of growth of the burbot have been limited. Martin (1941) made a preliminary study on 31 burbot from Algonquin Park, Ontario, but no extensive consideration of growth of this species has been made prior to the present study. The work reported here was subsidized by the Research Council of Ontario and the Ontario Department of Lands and Forests. Facilities for field and laboratory work were provided by the Department of Zoology of the University of Western Ontario and the W. F. Kolbe Co., Ltd., Port Dover, Ontario.

Methods of Age and Growth Determination

This study embodies the results obtained from the examination of 2,329 burbot captured by different methods from various ports along the north shore of Lake Erie, from May to December, 1946 (Table 1). Burbot were handled in fresh condition, usually on the day of capture. Total and standard lengths were measured to the nearest millimeter. The total length was measured in a straight line from the tip of the snout to the tip of the tail and standard length was measured from the

Table 1.—*Locality, month, and method of capture of burbot used for growth studies—1946.*

Month	Type of net	Locality					Subtotal	Total
		Port Dover	Port Burwell	Port Rowan	Port Stanley	Erieau		
May	Pound			263			263	263
June	Pound			310			310	338
	Trawl	28					28	
July	Pound			50			50	786
	Gill	736					736	
August	Gill	196					196	196
September	Gill	198					198	209
	Seine	11					11	
October	Gill	98					98	113
	Seine	14					14	
	Pound	1					1	
November	Gill	51				141	192	209
	Pound	17					17	
December	Gill		21		51	76	148	215
	Pound	67					67	
Total	Gill	1,279	21		51	217	1,568	2,329
	Pound	85		623			708	
	Trawl	28					28	
	Seine	25					25	

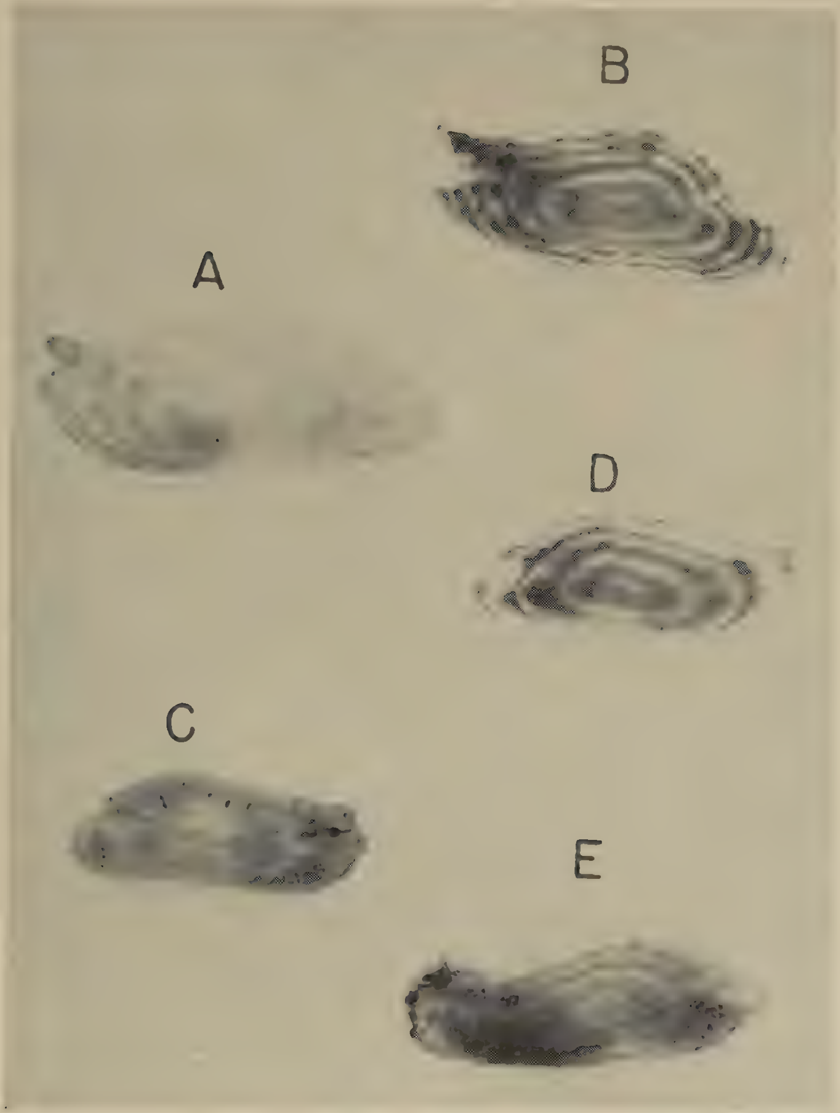

FIGURE 1.—Otoliths stored in various media. A—50 percent glycerine in water; B—3 percent tri-sodium phosphate; C—no storage medium; D—in fresh condition; E—endolymph from burbot.

tip of the snout to the end of the last vertebra. Weights were taken to the nearest estimated ounce on a type of Toledo scale commonly used in grocery stores. These weights were then converted to decagrams to provide a convenient unit of metric measurement within the range of weights encountered. The sex and state of maturity of the fish were determined from examination of the gonads.

Age was determined by the otolith method (Martin, 1941). Martin sectioned the otoliths for reading, but in the present study this procedure was not always followed since the annular rings could usually be detected by a simpler method. Otoliths were placed in a watch glass and covered with water. The watch glass was tipped to allow a uniform field of light to strike the convex surface of the otolith at right angles. In this position the annular rings were clearly visible (Figure 1). The sectioning method was used only to check fish over 6 years of age. Otoliths were read in a fresh condition just after they were removed from the fish and again after they were stored in a 3 percent solution of trisodium phosphate[1]. Otoliths kept in this storage medium were quite readable at the end of a year (Figure 1). Other storage methods, such as 50 percent glycerine in water with an antifermentation reagent (thymol), potassium hydroxide, normal saline, acetone, and alcohol were relatively unsuccessful.

RATE OF GROWTH

All fish of both sexes were combined to determine the general growth for burbot in Lake Erie from June to December, 1946. The rate of growth was based on mean lengths at capture of each age class rather than on calculations from otolith measurements (Table 2).

Exact ages of young-of-the-year burbot were unknown but age estimates (in months) were based on the assumption that the eggs of the burbot were hatched in early summer up until the last week of June (Fish, 1932). The monthly growth increment of young-of-the-year burbot captured in September and October suggested a relatively fast

TABLE 2.—*The mean standard length in millimeters at capture for each age class of Lake Erie burbot—sexes combined.*

Age class	Frequency	Mean standard length	Standard deviation
0	23	....	....
1	1	210.0	....
2	211	322.7	27.8
3	488	376.5	29.8
4	470	424.0	36.0
5	615	492.1	42.4
6	204	539.9	60.7
7	104	557.8	66.8
8	103	579.1	37.7
9	62	590.6	45.6
10	35	616.0	53.2

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[1] Jean-Paul Cuerrier, personal correspondence.

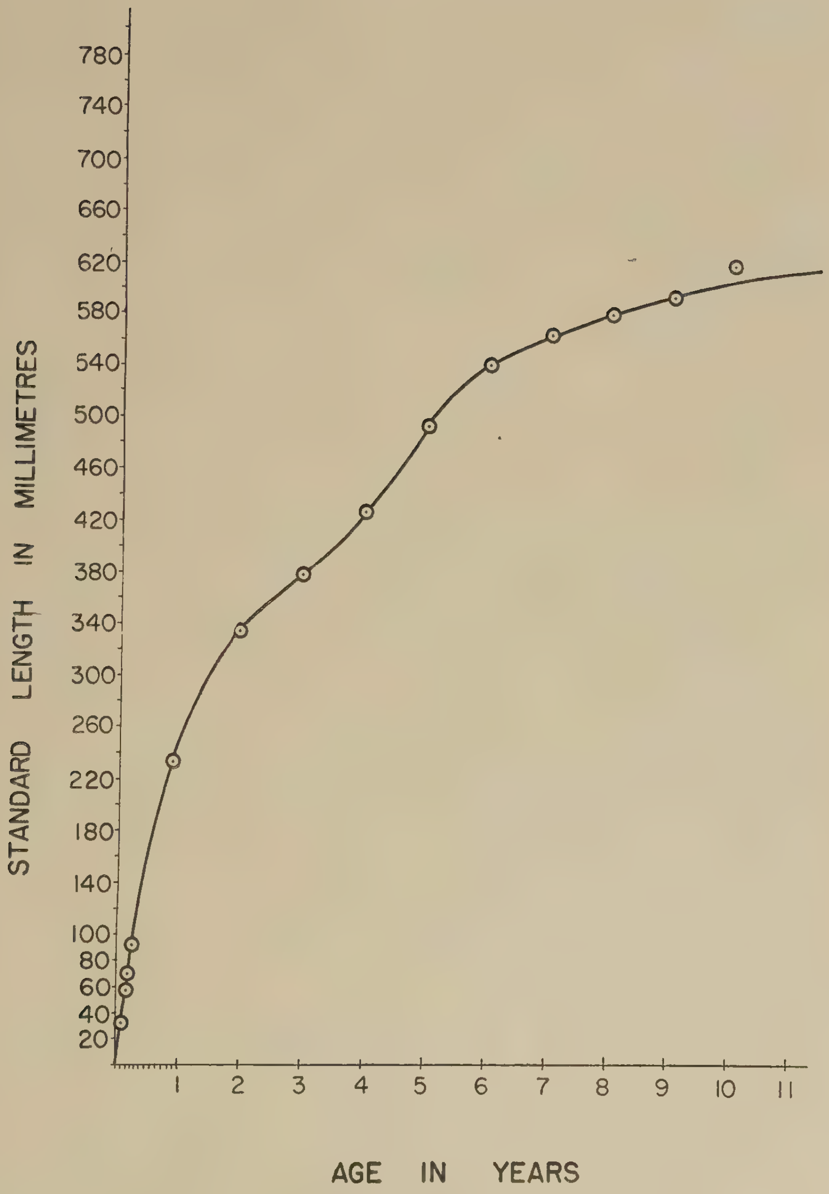

FIGURE 2.—The growth rate of burbot in Lake Erie from May to December, 1946.

growth rate in the first year. One yearling burbot obtained measured 210 millimeters.

The annual growth increment, determined by comparing the mean lengths of each year class, decreased with the age of the burbot. The increment of each year from the second to the tenth, was respectively: 112.0, 53.8, 47.5, 68.1, 47.8, 17.9, 21.3, 11.5, and 25.4 millimeters. However, the amount of growth during the third and fourth years appears to be relatively small, as is clearly seen by the dip in the growth-rate curve (Figure 2). The smaller growth increments at these points may have been the result of retarded growth during some period of unfavorable conditions and if compensatory growth has occurred, it had not offset the retardation.

On the other hand, growth retardation may be real instead of apparent during the burbot's third and fourth years of life. Although a real growth retardation may be the result of a combination of factors, two, the effect of arrival at sexual maturity and the type of food taken, were considered.

Over 80 percent of the burbot reached sexual maturity in their third and fourth years of life, i.e., during the period when the growth appeared to be retarded. This fact suggested that the growth-rate before and after this period of slow growth represents that of immature and mature fish. The growth-rate curve (Figure 2) further substantiates the suggestion that there are two types of growth which correspond to the mature and immature stages. The rate of growth of immature burbot was much greater than that of mature burbot.

Food analyses (Clemens, 1951) revealed that when burbot attained a length of 400 to 480 millimeters, fish replaced invertebrates as the predominant food. Then, in view of the age at which sexual maturity is reached, it is apparent that the major diet of mature and immature burbot was fish and invertebrates, respectively.

Variation in Growth Rate Between Sexes

The lengths of male and female burbot were separated to determine the variation in the growth rate between the sexes. The rate of growth for each sex was based on the mean lengths at capture of each age class (Table 3).

The mean length of females was greater than that of the males in all age classes from two to ten. A statistical test was applied to the 2-, 3-, 4-, and 9-year groups to determine whether or not a significant difference existed between the lengths of male and female burbot (Table 4). At the age of 4 years, females became significantly longer than males of the same age, and this condition prevailed for all older age groups.

TABLE 3.—*The mean standard length in millimeters at capture of male and female burbot of each age class.*

Age	Number of fish		Mean length at capture		Range of length	
	Male	Female	Male	Female	Male	Female
2	97	114	331.5	333.7	240—440	240—400
3	239	238	372.9	377.2	280—460	300—480
4	237	224	418.9	429.1	320—520	360—540
5	238	371	482.1	499.5	360—580	380—600
6	83	119	533.0	545.5	440—620	440—660
7	45	59	551.5	562.7	440—620	460—640
8	45	57	571.3	585.2	480—640	520—660
9	30	32	578.0	602.5	500—640	500—720
10	17	18	579.6	633.3	540—680	580—700

WEIGHT-LENGTH RELATIONSHIP

The weight-length relationship of burbot was determined from a combination of the data for both sexes (Table 5). When the weight was compared to the standard length of the fish, two relationships were apparent. One corresponded to the mature and the other to immature stages of the burbot (Figure 3). During mature life when burbot were from 500 to 700 millimeters long, the weight appeared to increase linearly with the length. The weight of smaller and immature burbot from 300 to 460 millimeters long, however, increased logarithmically with the length. This difference further corroborates the previous suggestion of two types of growth corresponding to the state of maturity.

AGE AND LENGTH AT MATURITY

Burbot matured in their third, fourth, and fifth years of life when they were between 300 and 480 millimeters in length (Table 6). No mature burbot were found smaller than 300 millimeters in length and

TABLE 4.—*Tests for significance*[1] *between the mean standard lengths of males and females of ages 2, 3, 4, and 9 years.*

Age	Sex	Mean length (millimeters)	Standard error	Length differences of the sexes	$\sqrt{SEM^2+SEF^2}$
2 2	Female Male	333.7 331.5	2.5 2.9	2.2	3.8
3 3	Female Male	377.2 372.9	1.9 1.1	4.3	2.2
4 4	Female Male	429.1 418.9	2.4 2.2	10.2	3.3
9 9	Female Male	602.5 578.0	8.8 6.8	24.5	11.1

[1] Significance is present if twice the root of the sum of the squares of each standard error is less than the difference in length of the two sexes of each year class.

TABLE 5.—*Average weights of burbot at successive 20-millimeter intervals from 270 to 669 millimeters total length.*

Length interval (millimeters)	Mean weight (decagrams)	Number of fish
270—289	26.25	8
290—309	26.96	33
310—329	31.55	71
330—349	37.10	138
350—369	42.64	197
370—389	50.34	201
390—409	59.20	215
410—429	65.34	206
430—449	75.36	166
450—469	89.01	142
470—489	109.35	155
490—509	122.22	162
510—529	133.98	173
530—549	147.79	172
550—569	162.00	110
570—589	178.96	116
590—609	193.68	76
610—629	211.28	39
630—649	227.20	25
650—669	261.11	9

all burbot longer than 480 millimeters were found to be mature. However, over 80 percent of the fish examined matured in their third and fourth years of life when they were from 340 to 440 millimeters in length.

Generally, there were relatively more mature males than females at each length interval (Table 6). This difference suggested that males matured at a smaller length than the females, as was reported by Bjorn (1940).

SPAWNING

Relatively little is known concerning the place of spawning of the burbot and existing reports are not in agreement. Bean (1903) stated that burbot spawn in deep water, while Cahn (1946) observed them spawning in shallow water. Bjorn (1940) reported that the burbot of Ring Lake, Wyoming, withdraw to their spawning bed, a large hole in a creek bed about one-half mile above the lake. Lake Erie fishermen provided different reports on the place of spawning, including claims for both shallow and deep water.

In this study, both ripe and spent females were caught throughout the spawning period in the open lake in 10 and 11 fathoms of water approximately 9 miles from the shore. Thus the place of capture and not the actual observance of the spawning act indicated the possibility of deep-water spawning. Cahn (1946) in Burntside Lake, Minnesota, observed burbot to come into the shallow water at night to spawn. This habit could be the case in Lake Erie and would require migrations of 18 miles or more from the deep to the shallow water and back. However, it should be noted that Fish (1932) captured larval stages of burbot in the open lake.

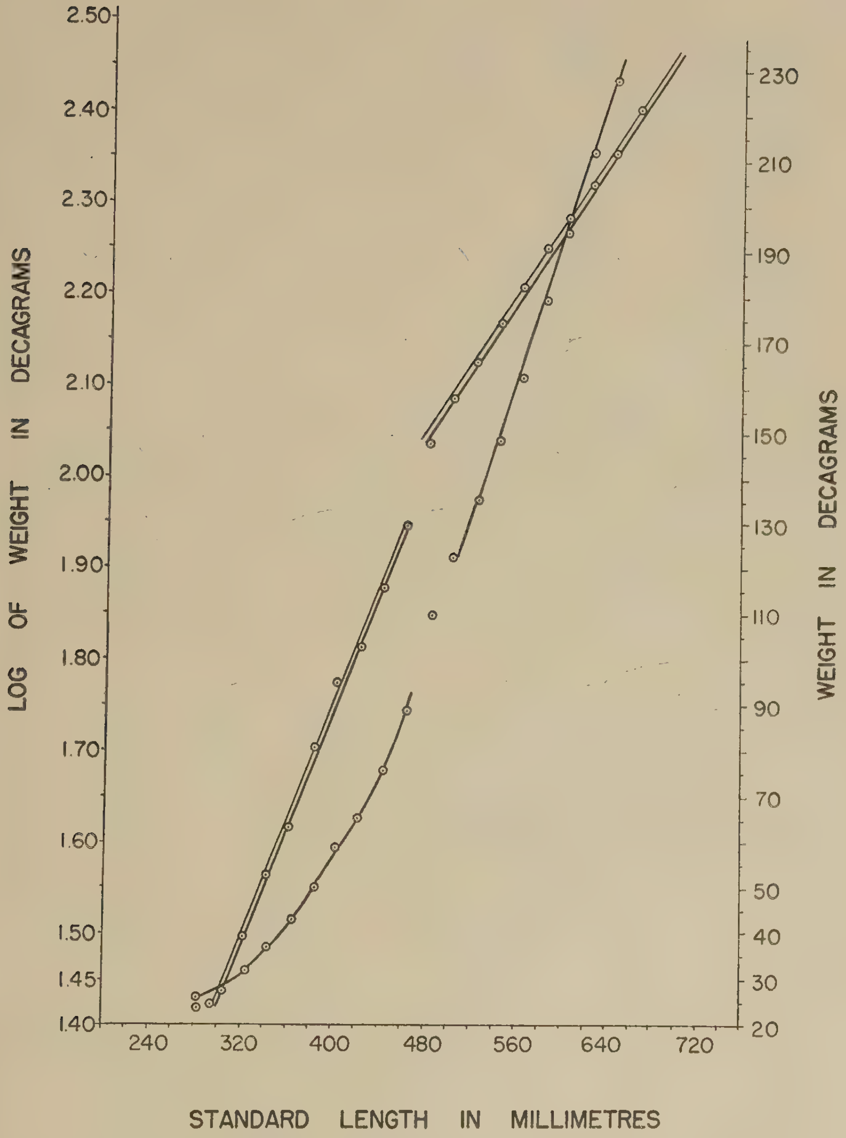

FIGURE 3.—The weight-length relationship of burbot in Lake Erie from June to December, 1946.

Table 6.—*Percentage of mature male and female burbot for each length interval of 20 millimeters.*

Length interval (millimeters)	Number of males	Percentage mature males	Number of females	Percentage mature females
250—269	1	0	0	0
270—289	4	0	2	0
290—309	14	0	16	6.3
310—329	49	14.3	47	14.8
330—349	94	24.4	99	18.3
350—369	171	39.7	155	27.7
370—389	138	34.1	156	25.6
390—409	193	72.6	231	62.0
410—429	202	87.6	189	82.6
430—449	154	94.2	107	92.5
450—469	62	96.9	52	96.2
470—489	72	97.2	85	97.7
490—509	42	100.0	44	100.0

Many authors report spawning dates of the burbot from various lakes and it is agreed that in general the burbot is a winter spawner. Bean (1903) reports that female burbot full of spawn have been taken from New York lakes from November to January. Cahn (1946) observed burbot spawning in Burntside Lake, Minnesota, on the following dates: February 14, 1931; February 10, 1932; February 18, 1933; February 5, 1934; February 7, 1935; and February 6, 1936. Bjorn (1940) recorded the spawning of burbot from two Wyoming lakes during the months of December, January, and February. Lake Erie fishermen generally agree that the burbot spawn in March and usually not later than April 15.

Observations in this study revealed that in 1947 burbot spawned in Lake Erie during the last week in March and the first week in April. There is a possibility that burbot in the deeper waters off Long Point near Port Dover spawned a few days later than the ones in the shallower central portion of the lake, as indicated in the following tabulation:

Port Stanley Collections (shallower central portion of the lake)
March 18—10 specimens examined, no spent females found; 4 of 5 males were exuding milt.
March 22—2/33 mature females spent (these 2 were the largest of the sample).
April 9—6/6 mature females spent.

Port Dover Collections (deeper eastern portion of the lake)
March 25—0/9 mature females spent.
March 31—1/11 mature females spent.
April 7—5/9 mature females spent.
April 11—6/17 mature females spent.
April 17—11/11 mature females spent.

PERIOD OF INCUBATION

Bean (1903) reports that the period of incubation of the burbot takes from 3 to 4 weeks. Under artificial conditions, Bjorn (1940) found that burbot eggs hatch in 30 days at a temperature of 6.1° C. Eddy and

Surber (1943) state that spent females have been taken in February and newly hatched fry about the middle of April.

The bottom waters of Lake Erie when the burbot eggs incubate are approximately 2° C. colder than those used by Bjorn. Hence, the period of incubation is expected to be prolonged. If we accept the first of April as the spawning date, the time of hatching would range from early May to June. This supports the contention by Fish (1932) which was previously used in the general growth-rate study.

MARGINAL ZONES OF OTOLITHS

On the basis of monthly collections and observations of otoliths throughout the year, a clear outer zone was noticed on otoliths examined from June to March, while a dark outer zone was evident on otoliths examined in April and May, just subsequent to spawning. Martin (1941) examined otoliths of specimens collected in Lake Opeongo, Ontario, from late July to December and found only clear outer zones. He believed the clear zone to be indicative of summer growth. From the data of the present study it is apparent that the dark zones or "annual marks" are formed in the early spring shortly after spawning and cannot be considered as strictly representative of winter growth.

ACKNOWLEDGMENTS

The author wishes to express sincere thanks to Drs. H. I. Battle, W. H. Johnson, and C. J. Kerswill for their interest and assistance; and to the many fishermen along the north shore of Lake Erie who provided the specimens for study.

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A METHOD FOR CALCULATING THE GROWTH OF CHANNEL CATFISH, *ICTALURUS LACUSTRIS PUNCTATUS*

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Abstract

Evidence from previous studies of the rings on bone structures of fish indicates that in a number of species they are true year marks. Among the species of fish to which this method has been applied is the channel catfish. In order to determine the possibility of computing growth during successive years of life by means of bone markings, the left pectoral spines were collected from 204 channel catfish from Grand Lake, Oklahoma. These spines were cut in cross-section near the base, and the radii of the several growth fields and of the entire spine were measured with a micrometer mounted on a binocular microscope. These measurements revealed a high coefficient of correlation ($r = 0.969$) between body length and spine radius.

The straight line fitted to the measurements of fish length and spine radius for 187 fish had an intercept of —3.24 millimeters of fish length. Since this intercept is zero for all practical purposes, growth calculations were made by direct proportion. Both the method of aging and calculating growth of channel catfish appear to be satisfactorily accurate, since (1) the number of spine rings increases as the average length of the fish increases; (2) the calculated length of age-group II at the end of the second year of life slightly exceeds the measured length of age-group I at the time of capture, and the growth to the third annulus of age-group III slightly exceeds the measured length of age-group II when captured in August; and (3) the markings on the pectoral spines of 50 channel catfish of known age corresponded to the markings as read on the spines collected from Grand Lake.

Introduction

The use of scales to determine the age of fish has been accepted for many years. In addition, scales afford the means for calculating growth during successive years of life. It has been demonstrated both experimentally and with statistical evidence that certain rings on scales separate growth zones, and that the growth in width of these zones can be employed to estimate the growth in length of the fish during each year of life. With this information in hand, Hile, Van Oosten, and others developed practical methods of growth calculations which are reasonably accurate for fish-management studies. Markings on bone structures such as otoliths, spines, and vertebrae have also been used to interpret the age of fish. The older literature was adequately reviewed by Moore (1948), who studied the markings on both the otoliths and scales of the sand flounder and concluded that these showed "good correspondence in age determination."

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[1] A cooperative enterprise of the Oklahoma Game and Fish Department and the University of Oklahoma Biological Survey.

Classen (1944) reviewed the literature of the Russian workers who have employed bone structures to determine the age and rate of growth of the sturgeon, *Acipenser sturio* L. Classen studied cross-sections of the bony rays (marginalia) of the pectoral fins of sturgeon and calculated their growth in length during successive years of life.

The bones of ameiurid fishes have been employed in the determination of their age. Kalman (unpublished thesis, Ohio State University, 1943) studied the vertebrae of yellow stonecat *(Noturus flavus)* and the channel catfish *(Ictalurus punctatus = I. lacustris punctatus)* and concluded that the rings represented annual markings. William H. Thompson, H. C. Ward, and Robert Jenkins (unpublished management reports, Oklahoma Game and Fish Department) found a close correlation between the lengths of channel catfish and the number of rings on the cross-section of the pectoral spines. Hooper (1949) studied the vertebrae of the madtom *(Schilbeodes mollis)* and believed that the dark rings represented year marks. He concluded that (1) regularity of increase in number of vertebral bands is accompanied by an increase in the size of fish, thus indicating that the bands are added systematically as growth proceeds; (2) modes in the length-frequency distribution coincide with the modal lengths of age groups based upon the number of vertebral bands. Lewis (1949) examined vertebrae to determine the age of northern black bullhead *(Ameiurus m. melas)*, but indicated a need for additional observations before positive conclusions could be drawn. Appelget and Smith (1951) successfully aged channel catfish from the vertebrae and calculated their rate of growth. This work was well validated by examination of fish of known age and by statistical treatment of the general data. Because it is difficult to secure vertebrae and the preparation and examination of them is tedious, an attempt has been made in the present study to age fish and calculate growth from pectoral spines.

Method of Collecting Spines

The pectoral spines of channel catfish are easily collected. Since they are removed free of all tissue except a thin layer of skin, they require no special treatment or preservation. To detach the left spine it was necessary to grasp it with a pair of pliers, pull outward to loosen the joint, and then rotate it in a clockwise direction. To remove the right spine the rotation was counter-clockwise. Sometimes it was necessary to cut the muscles surrounding the spines of very large fish. After removal, the spines were placed in standard scale envelopes on which were recorded the data concerning the fish from which it was removed. The spines were not placed in formalin because this procedure checks and cracks the bone and obscures the year marks. Spines were collected for the present study from fish killed with rotenone by William H.

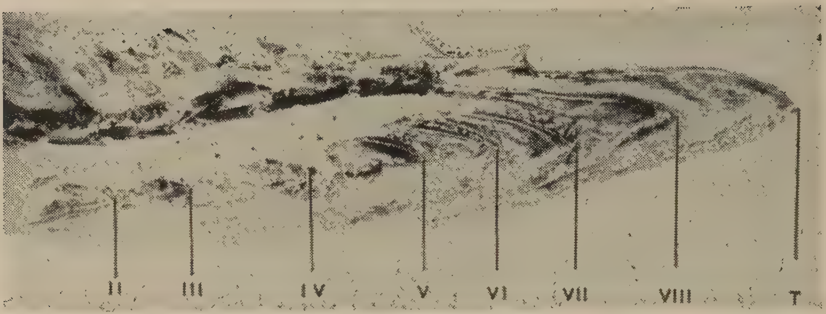

Figure 1.—Longitudinal section of tip of channel catfish spine. Roman numerals II to VIII indicate position of annuli. Annulus I is not shown.

Thompson and a group of biologists who conducted an investigation of the fishery resources of Grand Lake, Oklahoma. The 204 fish used here for age and growth studies constitute a random sample of the channel catfish which were collected.

Cutting and Measuring the Spines

It is apparent from an examination of Figure 1 that successful age determinations and calculations of growth must be made from spines which are cut so that each annual ring will be present on the cross-section. If a cross-section is cut too far toward the tip of the spine, the rings which represent cessation of growth during the first years of life will not be visible. It was found that a satisfactory cross-section could be cut near the base, or articulating portion, of the spine (Figure 2). On the surface of the channel catfish spine (Figure 2) the deep groove (A) ends abruptly at point B. Each spine was cut just clear of point B and then ground and polished so that the terminal

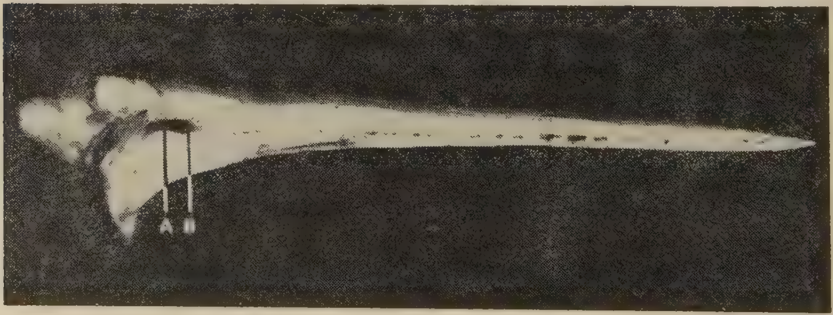

Figure 2.—Photograph of channel catfish spine. *A* indicates groove at the terminal end *(B)* of which the cross-sections were cut.

end of the groove began to show on the surface of the cross-section. An improvement on this method has been developed recently.[1] The mounting of the saw on a sliding platform in the new arrangement makes it possible to cut very thin cross-sections. When placed in water these thin wafers can be read easily and measured without being ground or polished. The outline of the spine cross-sections and of the zones of growth are irregular. The area which appeared to be the most regular and in which the rings were the most easily visible under reflected light was that shown in Figure 3. A micrometer with a movable cross-hair was used to measure the spine "radius" from the center of the lumen (along line AB, Figure 3) to marks representing successive years of life. The measurements were converted to millimeters and multiplied by 100 to facilitate computation. Discrepancies in the number of fish used in the various tables result from the fact that some spines could not be read and measured with confidence and were eliminated from the growth calculations.

TABLE 1.—*Relationship between spine radius and body length of 204 channel catfish of Grand Lake, Oklahoma, 1949.*

Radius of spine (millimeters x 100)	Number of fish	Average spine radius	Average total length of fish (millimeters)	Ratio of fish length to spine radius
50— 59....	2	53	68	1.28
60— 69....	1	61	75	1.23
70— 79....	3	77	103	1.34
80— 89....	7	85	106	1.25
90— 99....	14	94	115	1.22
100—109....	10	104	121	1.16
110—119....	10	116	142	1.22
120—129....	10	126	158	1.25
130—139....	10	135	167	1.24
140—149....	13	145	180	1.24
150—159....	19	155	198	1.28
160—169....	8	164	205	1.25
170—179....	12	175	227	1.30
180—189....	4	182	236	1.30
190—199....	13	194	242	1.25
200—209....	14	206	252	1.22
210—219....	6	211	270	1.28
220—229....	8	223	267	1.20
230—239....	8	234	289	1.23
240—249....	3	246	300	1.22
250—259....	4	255	316	1.24
260—269....	6	264	351	1.33
270—279....	2	277	428	1.54
280—289....	3	286	424	1.48
290—299....	2	294	377	1.28
300—309....	1	301	421	1.40
310—319....	4	314	437	1.39
320—329....	3	327	460	1.41
330—339....	1	337	576	1.71
340—349....	1	342	540	1.58
350—359....	....	....	....	....
360—369....	2	364	451	1.24
Total r Average (weighted).	204	....	....	1.26

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[1] Developed by James McArthur of the Oklahoma Fisheries Research Laboratory.

The Body-Length-Spine Relationship

The fish used in growth studies were also used to determine the relationship between body length and length of the radius on the spine section (Table 1). All data were plotted and two regression lines fitted by the method of least squares. The first, represented by the solid line of Figure 4, was obtained when 204 measurements were used in the computations. It has a slope of 1.41, an intercept of —23.10 millimeters and a correlation coefficient *(r)* of 0.951. The second regression line, represented by the dashes (Figure 4), was calculated with the 17 largest fish omitted. This line has a slope of 1.27, an intercept of —3.24 millimeters, and a correlation coefficient of 0.969. These 17 fish, which represent only 8.3 percent of the total number of fish studied, greatly

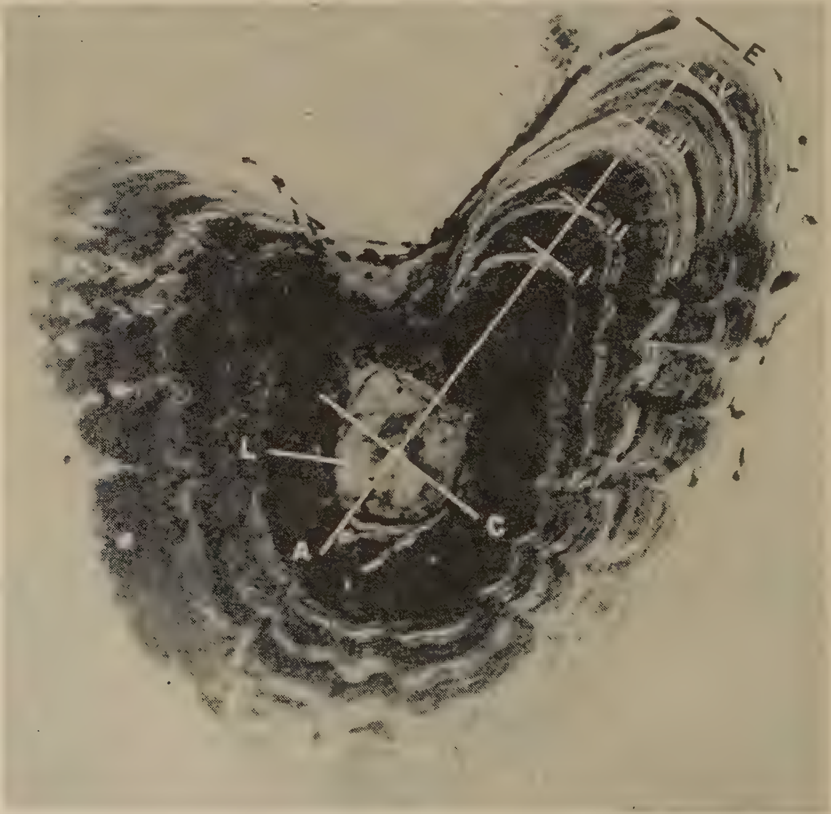

Figure 3.—Photomicrograph of cross-section of channel catfish spine, cut at point B, Figure 2. A B, line along which spine was measured; C, position of cross-hair when measurement is begun; E, edge of spine; L, lumen of spine; S, strands of skin; I, II, III, IV, annuli.

affect the slope and intercept of the regression line. It is also apparent that if the intercept, —23.1 millimeters, were used as a correction factor in calculating growth, it would be too low for most of the fish studied, since the average intercept for 187 of the fish is —3.24 millimeters.

The apparent error introduced by inclusion of the large fish may be caused by inadequate sampling of large fish, sex difference in spine size, and shift in sex ratio at the greater lengths, or it may in fact represent a curvilinear relationship rather than the assumed rectilinear described above.[1]

ASSESSMENT OF AGE AND RATE OF GROWTH

In order to justify use of age assessments based on spine rings some verification of their status must be attempted. In the present case two lines of evidence seem to warrant the assumption that the observed marks are true annuli. First, calculated lengths based on the assigned ages bear a rational relationship to observed empirical lengths. The calculated length of age-group II at the end of the second year of life slightly exceeds the measured length of age-group I at the time of capture. In like manner, the calculated growth to the third annulus of age-group III slightly exceeds the measured length of age-group II when captured in August. This relationship is true for every age group except age-group V in which there is an inadequate sample. The discrepancy may also be accounted for by the fact that the 1945 year class (age-group IV) apparently grew faster than any other class. It is also

TABLE 2.—*Grand average calculated total length at the time of annulus formation in 188 channel catfish, Grand Lake, Oklahoma, 1949.*

Age group	Year class	Number of fish	Average length (millimeters)	Calculated length at each annulus (millimeters)							
				1	2	3	4	5	6	7	8
0	1949	3	71	.....	.....	.....	.....	.....	.....	.....	.....
I	1948	41	120	62	.....	.....	.....	.....	.....	.....	.....
II	1947	60	181	67	131	.....	.....	.....	.....	.....	.....
III	1946	42	248	93	145	203	.....	.....	.....	.....	.....
IV	1945	24	300	96	159	214	265	.....	.....	.....	.....
V	1944	6	338	93	149	204	251	297	.....	.....	.....
VI	1943	6	429	79	141	209	273	342	391	.....	.....
VII	1942	3	463	80	186	240	287	341	389	430	.....
VIII	1941	3	559	87	208	253	315	379	435	483	519
Total or Average	....	188	....	77	144	210	269	333	401	456	519
Average annual growth increment	....	....	....	77	67	66	59	64	68	55	63

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[1] It has been suggested by Dr. Ralph Hile that the relationship may be better described by the general parabola, $Y = aX^n$.

TABLE 3.—*Length-frequencies of Grand Lake channel catfish in succeeding age groups—1949.*

Length interval (millimeters)	Age group								
	0	I	II	III	IV	V	VI	VII	VIII
60— 79	3								
80— 99									
100—119		23							
120—139		13	2						
140—159		6	8						
160—179			21						
180—199			13						
200—219			12	7					
220—239				11					
240—259		3	12	6					
260—279			8	6					
280—299		1	5	3					
300—319				3	1	2			
320—339					4	1			
340—359									
360—379					2	1	1		
380—399					2		1	1	
400—419						1	1		
420—439									
440—459							2		1
460—479								1	
480—499									
500—519							1		
520—539									1
540—559								1	
560—579									2

evident that as the number of spine rings increases the average length of the fish increases, suggesting that the rings are added systematically as growth proceeds (Table 3). Second, it has been possible to verify this method of aging catfish by the examination of 50 channel catfish of known age, obtained from Mr. Victor Graham of the Holdenville hatchery. Twenty-five were known to be 1 year old, and 25 were 2 years old. The spines were placed in formalin which caused the bone to check, but the year marks could still be determined. The markings on those of age-group I correspond with the markings on catfish of age-group I from Grand Lake; the same held for age-group II.

Since the sex of the fish in this collection was not determined, no division of the data could be made on this basis. It is probable that ossification of bone structures in catfish takes place at a very early age and, as shown above, the intercept of the regression line depends to a large extent upon the degree of sampling. Presumably, the most valid method of computing growth for this sample of channel catfish is by direct proportion with a zero intercept. The growth during successive years of life was calculated for each fish and then the average growth for each year of life for each age group was determined (Table 2). Up to the eighth year of life there appears to be no significant variation in annual rate of increment. This condition is in contrast to that found in many scaled fishes which often show a decline in growth

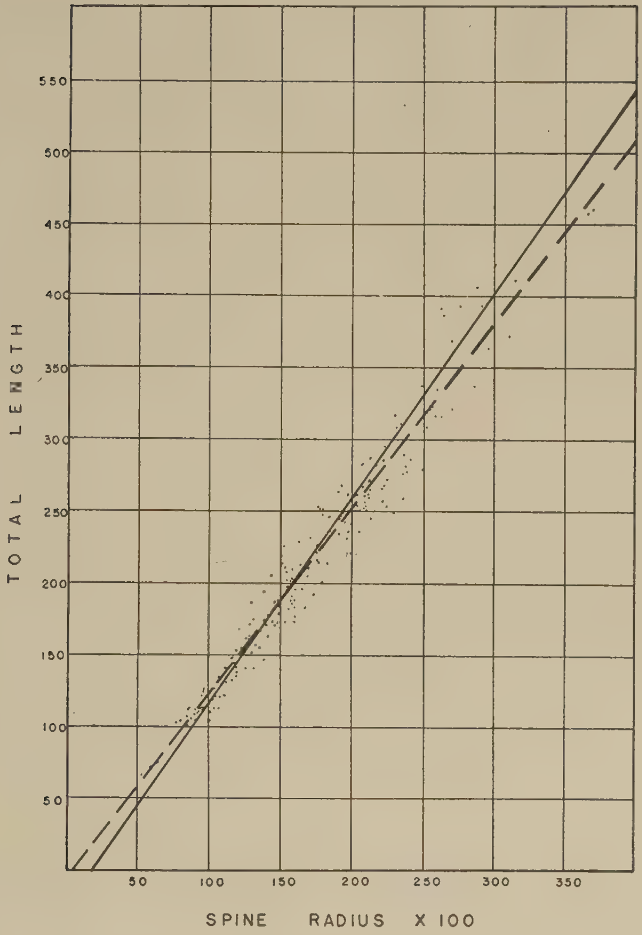

FIGURE 4.—Relationship between spine radius and total body length of channel catfish of Grand Lake, Oklahoma, 1949. The solid regression line was calculated from data for 204 fish. The broken regression line was calculated from 187 measurements (17 of the largest fish were omitted from the computations).

rate after sexual maturity, but it is consistent with the results of Appelget and Smith (1951).

The calculated growth at the end of the second, third, and fourth years of life is greater in older fish, indicating that the early year classes grew faster than those spawned in recent years. This relationship appears to be a reversal of Lee's phenomenon. In the majority of studies in artificial impoundments in Oklahoma, fish growth during the early years of impoundment was greater than the growth in later years. Ward (unpublished thesis) observed that the growth of white bass was greatest in the years immediately following the initial stocking of this species in Lake Duncan, Oklahoma. The white bass population increased until it became the dominant species in the lake, but as the population increased, the growth rate declined. Jenkins (unpublished thesis) demonstrated the same type of growth history for the river carpsucker in the Great Salt Plains reservoir. Thompson (unpublished data) observed that carp, bass, and several other fishes grew fastest during the early years of impoundment in Grand Lake, Oklahoma. Sneed and Thompson (unpublished data) concluded that the growth of the white crappie *(Pomoxis annularis)* and largemouth black bass *(Micropterus salmoides)* in Lake Texoma was greatest during the first 2 years of impoundment and rapidly declined in the year class spawned during the fourth year of impoundment.

Discussion of Method

Pectoral spines were used in this study because they are the easiest bones to collect in the field and handle in the laboratory. However, the irregular arrangement of the rings of growth presented some difficulties. Although several measurements might be made on the cross-section for calculation, the one which appeared to be least variable was along the line indicated in Figure 3. When 204 fish were used in the computations, the coefficient of correlation between total fish length and spine radius was 0.951; and when 187 fish were used, the correlation was 0.969. The coefficient of correlation between a fish's length and the length of a particular part will be higher for some parts or some measurements than for others. While it is desirable to use anatomical elements which have the highest correlation with length, the ease of collection and study must also be considered.

Measurements of the vertebrae, because they are more regular, might give a higher correlation than the measurements of the pectoral spines, but the additional work involved in their collection and preparation for study makes the method less desirable for practical management studies. However, the correlation of 0.969 obtained in this study for the catfish spines is considerably higher than the correlations usually obtained in studies of scaled fish in Oklahoma. The correlation between standard length and scale radius for 967 white crappie in Oklahoma was 0.858; for 182 black bass it was 0.879 (Sneed and Thompson, unpublished).

Acknowledgments

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THE NUMBER OF ERYTHROCYTES IN THE BLOOD OF THE SILVER SALMON[1]

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ABSTRACT

The mean blood count of 119 fingerling silver salmon from Swamp Creek, Washington, was 1,496,000 erythrocytes per cubic millimeter of blood. The data suggested that within a single collection the larger fish had a slightly higher blood count than that of the smaller fish. The average blood counts seemed to increase and decrease with changes in water temperature. The number of erythrocytes in silver salmon feeding in salt water and in salmon preparing to spawn was not greatly different from that of the fingerling fish.

INTRODUCTION

Accurate knowledge of the number of erythrocytes in the blood of fish is important to the biologist interested in fish physiology and nutrition. Blood counts have been used at times to evaluate diets (Marsh, 1902; Marsh and Gorham, 1906; Hoffmeyer, 1907) but it is only recently (Tunison, 1943; Riddell, 1948; Ellis, 1949) that erythrocyte counts have become routine procedures in some hatcheries. Such counts help evaluate hatchery diets because the number of red cells responds more quickly to some dietary deficiencies than does the condition factor or the growth rate. High mortalities attributed in part to inadequate diet could be averted by alert biologists who might interpret the observed anemias as indicative of poor nutrition.

In order that the biologist may evaluate the blood counts of his fish, some information as to the normal erythrocyte count is necessary. A literature search reveals some data that indicate normal blood values in salmonids belonging to the important genus, *Oncorhynchus.* Since much of these data were from hatchery fish, the present study was made of the blood of undomesticated fingerling, marine-feeding, and spawning silver salmon, *Oncorhynchus kisutch* (Walbaum), to get an idea of the blood picture of fish from a normal habitat which were subsisting on a presumably adequate food supply.

Before examining the data from these fingerling silver salmon, it would be well to note some blood counts of other fish species. Malassez (1872), one of the first to count the blood cells of fish, found that teleosts had more but smaller blood cells than the elasmobranchs. Wintrobe's (1933) count for mackeral blood, *Scomber scombrus,* with

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[1] This work was done at the School of Fisheries, University of Washington, under a grant from the Division of Research Grants & Fellowships, U. S. Public Health Service.

TABLE 1.—*The number of erythrocytes per cubic millimeter of blood of some salmonids.*

Species	Erythrocytes/mm^3	Reference
Salmo trutta	1,140,000	Schlicher, 1927
Salmo trutta (males)	1,990,000	Pavlov and Krolik, 1936
Salmo trutta (females)	1,850,000	Pavlov and Krolik, 1936
Salmo trutta	1,402,000	Hoffmeyer, 1907
Salmo trutta	766,000	Tunison, 1943
Salmo gairdnerii	1,100,000	Schlicher, 1927
Salmo gairdnerii (wild)	1,830,000	Marsh and Gorham, 1906
Salmo gairdnerii (domestic)	1,487,000	Marsh and Gorham, 1906
Salmo gairdnerii	1,428,000	Hoffmeyer, 1907
Salmo gairdnerii	1,220,000	Tunison, 1943
Salvelinus fontinalis	1,032,000	Tunison, 1943
Salvelinus fontinalis (wild)	1,000,000	Marsh and Gorham, 1906
Salvelinus fontinalis (domestic)	1,000,000	Marsh and Gorham, 1906
Salvelinus fontinalis (wild)	1,425,000	Hoffmeyer, 1907
Salvelinus fontinalis (domestic)	1,013,900	Field et al, 1943
Salvelinus fontinalis	1,090,000	Phillips, 1947
Wild trout	2,020,000	Smith, 1930
Liver fed trout	2,480,000	Smith, 1930
Cristivomer namaycush	642,000	Tunison, 1943
Oncorhynchus tschawytscha	1,500,000	Norris & Simmons, 1945
Oncorhynchus tschawytscha	1,270,000	Bonham et al, 1948
Oncorhynchus tschawytscha	1,500,000	Slater, 1950[1]

[1] Personal communication.

4,200,000 RBC per cubic millimeter, is the highest reported for any teleost. *Gobius exanthematicus* with only 425,000 red cells per cubic millimeter has the fewest erythrocytes of any fish reported in the literature (Barbudieri, 1930). Data obtained in this study and that of other authors (Table 1) show the number of blood cells of salmonids to be intermediate between those of the above marine species.

Of the salmonids, the lake trout, *Cristivomer namaycush* (Table 1) has the fewest erythrocytes, while the brown and rainbow trout have almost three times more red cells than this minimum. It is interesting to note that different blood counts are given for the same species of fish by different authors. Differences in diet of the domesticated fish may account for some discrepancies, but other variations in blood count noted in the wild fish are harder to explain. Pavlov and Krolik (1936) in their exhaustive study of the blood of the carp offer explanations for some of these variations. They found that the average blood count decreased for a time as the young carp grew and matured. The 0-year class carp averaged 3,060,000 erythrocytes per cubic millimeter; yearlings averaged 2,550,000, while 2-year-old males averaged 2,330,000 cells per cubic millimeter. A sexual difference was also noted at this age with the 2-year-old females averaging 1,910,000 cells. During the next year of life, the blood counts began to rise again with the 3-year-old males averaging 2,460,000 and the females 2,270,000. Male carp 4 to 8 years old averaged 3,900,000 erythrocytes per cubic millimeter and females of the same age averaged 2,580,000.

The data of Pavlov and Krolik indicate that the number of erythrocytes varies with age as well as sex. This study of salmon blood suggests other factors that might affect the average blood count.

METHODS AND MATERIALS

Monthly collections of fingerlings of an undomesticated race of silver salmon were made in Swamp Creek, a tributary of Lake Washington, King County, Washington. The young fish were captured by hand seine and were brought to the laboratories of the School of Fisheries, University of Washington, where they were placed in troughs of well-aerated water at approximately the same temperature as that of Swamp Creek. Blood counts were made on the day of capture.

In the collection of samples from those fingerlings (40 to 97 millimeters fork length) precautions were taken to get blood without water, mucus, or cells from other tissues. The living fish was wiped dry with a towel and special care was exercised to assure dryness in the caudal region. The caudal fin and part of the peduncle were cut off with a sharp scissors. Blood from the caudal artery was then easily picked up in red-blood-cell diluting pipettes. No attempt was made to select the fish from which blood samples were taken.

To differentiate erythrocytes from the leucocytes and thrombocytes in the counting chamber of the hemacytometer, a special diluting fluid (Yokoyama, 1947) was used. This fluid was made up from two stable stock solutions which were mixed in equal volumes immediately before use. Stock solutions were of the following composition:

No. 1—	NaCl	800 mg.
	KCl	40 mg.
	40% neutral formalin	10 ml.
	Dextrose	250 mg.
	$NaHCO_3$	50 mg.
	Distilled H_2O	40 ml.
No. 2—	Methyl violet	15 mg.
	Pyronin B	15 mg.
	Distilled H_2O	50 ml.

Yokoyama (1947) stated: "The erythrocytes are stained with various shades of lavender and can be distinguished from the leucocytes by their homogeneous appearance. The leucocytes possess irregular contours and assume a dark bluish color, while the thrombocytes remain unstained."

The blood counts were made by the routine hematological procedures described in numerous manuals and textbooks. Blood was diluted in the ratio of one part of blood in 200 parts of diluting fluid. After vigorous shaking, the suspension of cells was transferred to both counting chambers of a Levy type hemacytometer. The erythrocytes in both chambers were counted and the number of erythrocytes per cubic millimeter of blood were calculated by the following formula:

$$\text{RBC per cu. mm.} = \frac{\text{RBC in both chambers}}{2} \times 10{,}000$$

BLOOD COUNTS FROM FINGERLINGS

Silver salmon fingerlings large enough to yield sufficient blood for accurate counts were first obtainable in May. From May through November, 1948, monthly blood counts were made of fingerlings from Swamp Creek (Table 2). In addition, two series of fish were sampled from the Soos Creek Hatchery of the Washington State Department of Fisheries. Blood counts were made from 119 fish ranging in fork length from 40 to 97 millimeters. The counts varied from a minimum of 880,000 cells per cubic millimeter in a 52-millimeter fish, to 2,120,000 cells in an 82-millimeter fish. The smallest fish in the collections (40 millimeters) had 932,000 erythrocytes and the largest (97 millimeters) had 1,820,000 cells. The average count for the 119 fingerlings was 1,496,000 per cubic millimeter.[2]

SEASONAL VARIATIONS IN THE NUMBER OF ERYTHROCYTES

Blood counts made on different dates (Table 3) indicated that there was a seasonal variation in the mean number of erythrocytes. The mean blood count of the fishes collected during the summer season was in all cases higher than that of fish of the same size taken during the spring and autumn months. The mean erythrocyte count of all fish taken from Swamp Creek during the spring was significantly lower than those taken during the summer; and the mean erythrocyte count

TABLE 2—*The mean number of erythrocytes per cubic millimeter in the blood of silver salmon fingerlings taken during the spring, summer, and autumn of 1948. Water temperatures expressed as degrees centigrade.*

Date of collection	Number of fish examined	Mean fork length of fish in millimeters	Mean erythrocyte count	Water temperature
May 16, 1948	6	46.6	1,365,000	....
May 19, 1948	2	....	1,320,000	....
May 24, 1948	7	55.9	1,294,000	....
May 26, 1948[1]	18	56.1	1,428,000	....
June 18, 1948	8	46.0	1,468,000	15.2
June 23, 1948	9	46.4	1,361,000	....
July 16, 1948	11	49.9	1,605,000	17.3
July 28, 1948[1]	10	59.6	1,689,000	....
August 20, 1948	12	49.6	1,724,000	15.2
September 13, 1948	14	70.7	1,667,000	14.0
October 18, 1948	12	72.8	1,508,000	8.0
November 18, 1948	10	79.2	1,567,000	5.0

[1] Soos Creek Hatchery fish; all other fish from Swamp Creek.

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[2] The standard deviation of the mean was 234,000 and the standard error of the mean, 21,510.

Table 3—*The mean erythrocyte counts of the various size classes of silver salmon fingerlings taken during 1948. Number of fish in each group in parentheses.*

Fork length (millimeters)	All fish	Fish taken during the		
		Spring (May—June)	Summer (July—September)	Autumn (Oct.—Nov.)
40—49	1,407,000 (31)	1,357,880 (25)	1,611,833 (6)	
50—59	1,500,356 (28)	1,397,499 (18)	1,685,499 (10)	
60—69	1,577,321 (28)	1,510,000 (6)	1,673,124 (16)	1,389,166 (6)
70—79	1,604,166 (24)	1,550,000 (1)	1,655,356 (14)	1,530,555 (9)
80—89	1,720,000 (5)		2,120,000 (1)	1,620,000 (4)
90—97	1,768,333 (3)			1,768,333 (3)
Mean	1,496,000	1,394,120	1,671,914	1,540,772
Total fish	119	50	47	22

of the fall fish was significantly less than those of the summer collections. The "t" value, 9.36, calculated for the difference between the means of the spring and summer counts and the "t" value, 3.54, calculated for the difference between the means of the summer and autumn erythrocyte counts were highly significant.

Unfortunately, during the course of the fish collections, extensive determinations were not made of the various physical and chemical changes that took place in the waters of the stream. The only data recorded were the water temperatures. Changes noted in the average blood counts cannot be attributed to temperature alone, but it is well known that the metabolic processes of all organisms are markedly influenced by the temperature. For example, Gardner and Leetham (1914) and Graham (1949) found that the oxygen requirements of trout increased with the increase in water temperatures. The observed increase in the number of erythrocytes could be a compensatory mechanism used to facilitate the transport of the additional oxygen required.

It was observed (Table 2) that from May to August, the average erythrocyte count increased to a peak of 1,724,000 cells and then declined to a low of 1,508,000 cells in October. The difference between the mean number of erythrocytes in the August collection and the low October collection was significant; a "t" value of 2.54 for 22 degrees of freedom was calculated. A "t" value of this magnitude would be due to chance only twice in 100 pairs of samples (Snedecor, 1946).

The isolated water temperatures, recorded in Table 2, are a general indication of the trends in water temperatures in Swamp Creek. Nevertheless, there seems to be a good correlation between the increase and decrease in the average blood counts with the increase and decrease in water temperatures. After changes in the water temperatures, there is a lag before any apparent effect is reflected in the mean blood counts. Wintrobe (1946) suggests as an explanation for this lag, that the life span of the human erythrocyte is believed to be 120 days and that 0.83 percent of the blood is replaced each day. Although no estimates of the life of the fish erythrocyte have been found, it is not unreasonable to assume that if there were a lessening of the hemoglobin requirements of the fish, some time would elapse before enough red cells would be destroyed to show in the blood counts.

Some observations made while examining the blood of the September fish may indicate the destruction of excess blood cells during the period when the autumn decline in water temperatures began. Although most of the erythrocytes were normal in appearance, a number of them were uniquely stained. These dark blue cells were in striking contrast to the lavender stain of the normal cells. It was assumed that these were effete or excess cells which were destined for early destruction.

Dissolved-oxygen determinations were not made in conjunction with the fish collections. It is possible that the increase in water temperatures may have lowered the oxygen content of the stream water enough to cause slight compensatory increase in erythrocytes. It is difficult, however, to understand how a calculated difference of 1.7 p.p.m. of dissolved oxygen between August and October (a 15 percent decrease) could cause an increase in erythrocytes of 13 percent, considering that Phillips (1947) found that a 49 percent decrease in oxygen content causes only an 11.4 percent increase in the number of trout erythrocytes. By November, the downward trend in blood counts had apparently ceased since the average cell count that month was slightly higher than in October. The disappearance of the fingerling fish and the high waters of the winter season prevented any further fish collections from Swamp Creek. During February, 1949, however, the writer made some blood counts of silver salmon fingerlings at the Minter Creek Experimental Hatchery of the Washington State Department of Fisheries (Ellis, 1949). These young salmon had been on various experimental diets and had blood counts varying from an average of 993,000 for one group on an inferior diet, to an average of 1,455,000 for another batch on a superior diet. The water temperature at that time was close to freezing.

Katz and Donaldson (1950) observed that hatchery-reared silver salmon fed presumably adequate diets have blood counts that are equal to, if not slightly greater than those of wild fish. It is assumed, therefore, that the average blood count of silver salmon fingerlings remains at a level during the winter months which is fairly high but does not approach the high counts observed in the summer collections. These findings with the blood of silver salmon agree with those of Schlicher (1927) who observed that the blood count of rainbow trout falls in the autumn months from the high counts of the summer and remains at a fairly constant level during the winter months.

Since the data reported above resulted from field observations only where no controlled conditions were possible, it would be extremely desirable to check these observations under laboratory conditions.

RELATION OF FISH SIZE TO BLOOD COUNT

Most biologists have recognized that one of the major factors limiting fish production in otherwise suitable habitats is the food supply. This limitation is apparent in the relatively poor salmon streams of the Pacific Coast where moderate spawning success will fill the streams with large numbers of salmon fingerlings which compete for the small amount of available food. The sudden spurt in growth of anadromous salmonids when they reach the ocean indicates that the salmon fingerlings are in a state of chronic semi-starvation while in the stream habitat. If the variation in size among the fingerlings in our collections reflects a more adequate food intake by the larger fish then it might be anticipated that the larger fish would have a higher blood count.

Actual blood counts (Table 3) bear out this expectancy since there is a consistent increase in the average erythrocyte count as the size of the fish increases. This evidence is, however, not conclusive because most of the larger fish were taken during the summer season when higher water temperature may have caused higher blood counts. Therefore, the blood counts of single collections of fish were plotted against the fork length of the fish and regression lines were fitted to these data.

For the May, 1948, collection, the following regression formula was obtained:

$$Y = 7.00\ X + 1{,}045{,}000$$

where Y is the number of erythrocytes per cubic millimeter and X is the fork length of the fish in millimeters.

Another regression line was fitted to the length and erythrocyte counts of the fish in the combined September and October collections and the following formula was obtained:

$$Y = 4.89\ X + 1{,}243{,}000$$

These regression formulae show that the larger fingerlings of a collection usually had more red cells per cubic millimeter than the smaller fish. The greater slope, 7.00, of the May regression formula indicates that the increase in the erythrocytes per unit increase of fish length is greater for the smaller fish taken during the spring months than for the larger fish taken during the early fall.

These observations agree with other hemopoietic phenomena of young salmonids. Welander et al. (1948, p. 229) noted a general decrease in the rate of mitoses in the hemopoietic tissue of young king salmon with age and development. The lesser slope of the regression line for the fish in the September and October collections suggests a reduced rate of hemopoiesis as compared to the fish in the May sample. However, the coefficient of correlation for the length of the fish and the erythrocyte count was 0.23 in the May sample, and was 0.15 in the September and October collections. Neither of these correlations is significant and neither of the calculated slopes can be proven to be significantly different from each other or from a slope of zero. These observations, however, should not be discarded on this account. Although it is obvious from previous work that the size of a fish is merely one of several factors that may affect the number of erythrocytes, the data obtained in the present study indicate that size of the fish may be correlated with the number of red cells, at least in the rapidly growing fingerlings.

Although the above regressions could not be proven to be significant these findings are felt to be of some practical value because many experiments on salmon nutrition use fish in the same size ranges which were observed in this study. For example, if a feeding experiment is planned using red cell counts as an indication of the hemopoietic value of various diets, samples of fish that are of the same length should be employed to minimize the differences in count that may be caused by varying fish size.

COUNTS FROM MATURE FISH

Nine sexually mature fish taken at the Soos Creek Hatchery gave counts which varied from 895,000 to 1,775,000 erythrocytes per cubic millimeter with a mean of 1,385,000. The red cell counts, although averaging less than those of the salt-water-feeding fish and fingerlings, do not differ enough to warrant the conclusion that the pre-spawning activities and the fresh-water fast caused a marked anemia.

Although several attempts were made, circumstances did not allow more than two blood counts of salmon feeding in salt water. These counts, one from a male of 68.5 centimeters fork length, which had 1,590,000 erythrocytes per cubic millimeter and the other from a female of 61.5 centimeters with 1,585,000 cells, indicates that these fish differ little in blood count from those feeding in fresh water. In general, it is believed that the average erythrocyte count of the spawning and the marine-feeding fish is similar to that of the fingerlings in fresh water.

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FISHERY MANAGEMENT OF CLAYTOR LAKE, AN IMPOUNDMENT ON THE NEW RIVER IN VIRGINIA

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ABSTRACT

Claytor Lake in Southwest Virginia, covering 4,495 acres of a mountainous section of Pulaski County, was formed by the construction of a dam in 1939. The lake is 21 miles long, has a maximum width of one-half mile, and a maximum normal pool elevation of 1,846 feet above sea level. During the period 1939-1946 the lake was stocked with 650,000 walleye fry, 74,854 young bluegills, 3,570 adult bluegills, 12,040 adult yellowbelly sunfish, 20,135 young largemouth bass, 10,813 adult largemouth bass, 3,000 young smallmouth bass, and 3,894 young white crappie. In spite of the heavy stocking, largemouth bass and yellowbelly sunfish failed to become important species in the lake.

Until 1946 the impoundment was closed to walleye and bass fishing each year from December 31 to June 20. After 1946 all fishing was prohibited during the December 31 to June 20 period. The fishes of Claytor Lake exhibit slow growth for the first year but after the second year the growth rate is considered good. The bluegill is the principal forage fish, but its population is restricted by competition with the channel catfish and crappie for food. Angling success on Claytor Lake is usually low.

In 1948 the best fishing occurred during June and October when returns of 0.11 and 0.14 pounds of fish were caught per hour and the poorest fishing was in August with a return of 0.072 pounds of fish per hour. The harvest of bluegill, white crappie, walleye, and channel catfish by anglers was low during the 1948 and 1949 fishing seasons. Tagging returns suggest that anglers realized the highest rate of harvest, a 20 to 30 percent return, from spotted and smallmouth bass.

As a result of the findings of the Claytor Lake fisheries investigations, it was recommended that: (1) the fishing season be extended to the entire 12 months for all species of fish with the exception of the black basses, for which the season should be closed during the months of April and May; (2) the introduction of the gizzard shad be investigated for producing a plankton-shad-bass and walleye food chain; (3) attempts be made to popularize the fishing for bluegill, crappie, and channel catfish to increase the harvest of these species; (4) creel census be continued to determine any changes in the composition of the fish population, in sport fishing conditions, and in the approximate harvest of sport-fish populations; (5) fish collections be made to determine current food habits, population changes, age-growth rate, and similar life history data.

INTRODUCTION

Information on the status of fish populations and their management in impounded waters has been secured for many important river systems. The present study is an attempt to extend this information and obtain

TABLE 1.—*Physical and hydraulic characteristics of Claytor Lake and dam (Sporn and Kammer, 1941).*

Approximate drainage area (square miles)	2,400
Average flow (cubic feet per second) at the dam	3,000
Maximum recorded flow (cubic feet per second) at the dam (August, 1940)	200,000
Total length along center line of river (miles)	21.67
Shoreline distance around 1,850-foot contour (miles)	101.54
Acres of land covered (7.03 square miles)	4,495
Acre feet in reservoir	225,000
Acre feet draw-down	95,000
Maximum height from rock line to top of spillway gates (feet)	123
Length of dam (feet)	1,150
Normal pool elevation (feet)	1,846
Turbine elevation (feet)	1,740
Lower elevation of penstocks (feet)	1,785

specific facts for fishery management of Claytor Lake, a 4,495-acre mainstream impoundment in the New River, Virginia. This impoundment was created in Pulaski County by the construction of a power dam by the Appalachian Power Company.

New River originates in the northwest corner of North Carolina and flows in a northerly direction across the Allegheny Mountains and thence into West Virginia. Sixty miles into the interior of the state its name changes to the Kanawha River and as such it continues to flow in a northwesterly direction, finally discharging into the Ohio River at Point Pleasant, West Virginia. The Claytor Lake drainage area is estimated to encompass approximately 2,400 square miles. Within this watershed the soils are derived from igneous and sedimentary rock formations and are subject to slight or moderate sheet erosion.

Commercial operation of the Claytor hydro-power plant began August 1, 1939, and by April 20, 1940, the plant was operating under a full head of water with the normal pool elevation at 1,846 feet above sea level. Other physical and hydraulic data for Claytor Lake and dam are presented in Table 1. Like all impoundments in mountainous districts, Claytor Lake is deep and narrow with rather precipitous shores.

ENVIRONMENTAL CONDITIONS IN CLAYTOR LAKE

During periods of low rainfall the waters of this reservoir may have the characteristics of standing lake water. On the other hand, the basin is of such shape that the waters may be replaced in a relatively short time by heavy precipitation and may assume many characteristics of a flowing stream.

Routine observations were made of various chemical and physical conditions of the lake during 1948 and 1949. The waters are stratified thermally (Table 2) into a thick, warm, and well-oxygenated epilimnion extending from the surface to a depth of about 70 feet, a thermocline about 20 feet in thickness, and a hypolimnion which extends downward from the 90-foot level. The latter layer is cold, deficient in dissolved

TABLE 2.—*Temperature, dissolved oxygen, carbon dioxide, pH, and methyl-orange alkalinity of Claytor Lake, 3 miles above the dam, recorded for 10-foot intervals during August, 1948.*[1]

Depth in feet	Temperature (Fahrenheit)	Oxygen (percent saturation)	Carbon dioxide (p.p.m.)	Alkalinity (p.p.m.)	pH
0	78.5	99	0	37	8.3
10	77.5	96	0	38	8.2
20	76.0	90	1.5	37	7.6
30	74.0	67	2.0	38	7.3
40	74.0	64	2.0	38	7.2
50	73.0	59	3.0	39	7.0
60	72.0	63	4.1	35	6.9
70	70.0	60	4.1	32	6.8
80	58.5	02	10.2	62	6.8
90	54.0	02	8.1	59	6.7
100	52.5	01	....	61	6.7

[1] Temperature and dissolved oxygen recorded for August 21; other data recorded for August 28.

oxygen, and high in carbon dioxide and bicarbonates. During the summers of 1948 and 1949 the thermocline formed during the latter part of June and disappeared by the middle of October.

The temperature of the surface water is affected by the incoming waters in the spring. Warm water which flows into the lake remains at the surface while colder water moves along the bottom or mingles with waters of approximately the same density. In the summer the density flow is usually along the bottom of the reservoir until an approximate depth of 70 feet is reached and then the density current continues at this level through the lake and out the penstocks, which are 62 feet below the normal water level. In the fall the cooling of the epilimnion is gradual since the cool inflowing waters have a tendency to form a density current along the bottom of the reservoir rather than displacing the upper stratum.

The water level seldom fluctuates more than 10 feet during the year, and there is rarely a rapid, continuous drop of the water although it may fluctuate 6 to 18 inches in 1 day. Heavy drawdowns that would be disastrous during spawning season have never occurred in the lake. There is a constant erosion of the banks over a narrow vertical region which prevents the establishment of shoreline flora. Furthermore, the fine silt eroded from the shore and deposited in shallow waters prevents the development of abundant littoral forms. Most of the banks with more than a 20-degree slope have plants of the dry oak-chestnut climax. The sedges have been able to gain a slight foothold in the coves with a very gradual slope.

Waters of the reservoir are most turbid near its head and usually become clearer as the dam is approached. From November, 1948, to September, 1949, the average of 28 Secchi-disc readings was 65.1 inches at a station 3 miles above the dam. It may be expected that the behavior

TABLE 3.—*The number of each species of fish stocked in Claytor Lake during 1939-1946.*[1]

Year	Species							
	Walleye	Bluegill		Yellowbelly sunfish	Largemouth bass		Smallmouth bass	White crappie
	Young	Young	Adults	Adults	Young	Adults	Young	Young
1939	250,000	8,979	1,670	3,040	6,220	1,400	...	...
1940	200,000	31,750	1,900	...	3,300	1,394	...	...
1941	150,000	8,525	...	...	...	700	...	...
1942	...	8,500	...	...	8,100	2,100	...	...
1943	...	...	...	...	560	1,400	...	2,400
1944	...	1,500	...	1,000	875	1,719	2,000	...
1945	25,000	15,600	...	8,000	1,080	700	1,000	...
1946	25,000	...	...	...	...	1,400	...	1,494
Total	650,000	74,854	3,570	12,040	20,135	10,813	3,000	3,894

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[1] Fish were supplied by the Virginia Commission of Game and Inland Fisheries and the United States Department of Interior, Fish and Wildlife Service.

of fish is affected by the transparency of the waters. As will be noted later, the highest concentration of smallmouth bass is in the clearer region of the lake.

FISH MANAGEMENT PRACTICES

The Virginia Commission of Game and Inland Fisheries, in cooperation with the Fish and Wildlife Service, stocked Claytor Lake each year from 1939 to 1946 with walleye (*Stizostedion vitreum*), yellowbelly sunfish (*Lepomis auritus*), largemouth black bass (*Micropterus salmoides*), smallmouth black bass (*Micropterus dolomieu*), and white crappie (*Pomoxis annularis*) (Table 3). The greater part of the stocking effort was concentrated on supplying 10,813 adult largemouth black bass. Certain fishing limitations have been in effect on the lake since its impoundment. The minimum size of bass which can be taken is 10 inches, and the daily bag limit is 10 fish. The daily creel limit of walleye has been 20 fish. There is no size limit on panfish. The aggregate of all fish removed in 1 day cannot exceed 25 fish.

Until 1946, the lake was closed to walleye and bass fishing each year from December 31 to June 20 (opening of the regional bass season), but fishing for bluegills, crappie, and catfish was permitted during the entire year. After May 1, 1946, all fishing was prohibited on the lake between December 31 and June 20 in the belief that bass would be protected against the poaching which went on during the winter and early spring months in the guise of bluegill and catfish angling.

THE FISH POPULATION

Because all fish-sampling methods tend to be selective, several devices were employed in an effort to obtain a satisfactory picture of the fish population. These methods included rotenone, gill nets, hoop nets, and hook and line. The number of species of fish found in Claytor Lake

TABLE 4.—*Species of fish collected from Claytor Lake and their relative abundance (A — abundant, C — common, R — rare) in 1948-1949.*

Species	abundance
Hypentelium nigricans (LeSueur). Hog Sucker	C
Cyprinus carpio Linnaeus. Carp	C
Notropis hudsonius (DeWitt Clinton). Spottail Shiner	R
Notropis analostanus (Girard). Satinfin Shiner	R
Ictalurus lacustris (Rafinesque). Channel Catfish	A
Pilodictis olivaris (Rafinesque). Flathead Catfish	R
Stizostedion vitreum vitreum (Mitchill). Walleye (Yellow Pikeperch.)	A
Perca flavescens (Mitchill). Yellow Perch	R
Micropterus dolomieu dolomieu Lacepede. Smallmouth Black Bass	A
Micropterus punctulatus punctulatus (Rafinesque). Spotted Bass	A
Micropterus salmoides (Lacepede). Largemouth Black Bass	R
Lepomis cyanellus Rafinesque. Green Sunfish	C
Lepomis gibbosus (Linnaeus). Pumpkinseed	C
Lepomis macrochirus Rafinesque. Bluegill	A
Ambloplites rupestris (Rafinesque). Rock Bass	R
Pomoxis nigro-maculatus (LeSueur). Black Crappie	R
Pomoxis annularis Rafinesque. White Crappie	A

TABLE 5.—*Stomach contents of six species of game fish collected from Claytor Lake in 1948 and 1949 — expressed as number of fish containing each food item.*

Species	Number of specimens	Food Item										
		Debris	Algae	Zoo-plankton	Insect larvae	Adult insects	Crayfish	Fish remains	Bluegill	White crappie	Channel catfish	Bass
Bluegill	41	....	4	3	5	14	....	....	....	....	....	....
Channel catfish	126	17	12	....	10	46	5	9	4	1	....	....
White crappie	184	....	....	8	28	31	....	17	30	2	....	....
Spotted bass	311	....	1	....	....	11	27	22	70	5	2	1
Smallmouth bass	62	....	....	....	....	3	4	10	17	1	....	2
Walleye	221	....	....	....	3	....	1	49	62	40	11	12

proper was relatively small (Table 4), but many other species occur in tributary streams.

Since the water level of Claytor Lake is variable and the rocky precipitous shores are extremely vulnerable to wave action, the shore zone does not develop a high population of plant or animal forms. Because the principal forage fish, the bluegill (Table 5), is dependent upon this zone for food, its abundance is restricted and the standing crop of game fish is consequently low. The forage fish population may be further restricted because the channel catfish and white crappie compete with the bluegill for food.

The fishes of Claytor Lake grow slowly during the first year when competition among all species is greatest, but after the second year the growth rate is good. At the end of the third year the Claytor Lake spotted bass reached 10.7 inches, smallmouth bass 10.9 inches, largemouth bass 13.6 inches, walleye 18.4 inches, white crappie 8.0 inches, bluegills 6.0 inches, and yellow perch 8.5 inches in total length (Table 6). The growth rates of the basses were slower than those given by Stroud (1948) for Norris Reservoir (Table 6). The growth rates of the white crappie, bluegill, walleye, and yellow perch are also summarized and compared in Table 6 with the growth of the respective species in other waters.

THE FISH HARVEST

Specimens were captured, tagged, released, and recaptured to obtain information for estimation of fish harvest and species composition of the population. Creel census was also conducted in an effort to evaluate the harvest. Fish-tagging operations were carried out during the spring months from April 24 to June 20, 1948, and from April 10 to June 20, 1949. During the first year fish were captured for tagging from a number of regions in the lake, but in 1949 tagging was conducted principally on the lower portion of the impoundment. Angling was the chief method used to capture specimens for tagging, but crappie were also caught in hoop nets in 1949. Serially-numbered jaw tags were used to mark fish and their length and location of release were recorded. All bass and walleye above 9½ inches and all crappie above 9 inches were marked with Number 3 metal strap tags. All crappie between 7 and 9 inches were marked with Number 1 tags.

An estimate of the extent of the harvest from the available game fish population was based on the percentage of tagged fish recaptured. It was assumed that the tagged fish and untagged fish were equally vulnerable to angling. The minimum size of bass and walleye which were tagged was 9½ inches and the minimum size of crappie was 7 inches. These fish were considered to be the smallest fish in the harvestable population with the exception of some of the 7-inch crappie.

A total of 694 bass were tagged in 1948 and 1949 and 208 or 30 percent of these fish were returned (Table 7). Spotted bass showed a 28

TABLE 6.—Average total length of Claytor Lake fish (in inches) of each age group and average total length of the same species in other waters (1948-1949).[1]

Species and location	Number of specimens	Age groups							
		1	2	3	4	5	6	7	8
Spotted bass									
Claytor Lake	359	3.1	7.0	10.7	13.1	15.1	16.1	17.9	....
Norris Reservoir (Stroud, 1948)	....	4.9	10.3	13.2	14.9	16.1	16.4	16.7	....
Smallmouth bass									
Claytor Lake	83	2.4	6.8	10.9	14.1	16.9	20.4	22.0	....
Norris Reservoir (Stroud, 1948)	....	3.1	8.9	13.3	15.8	17.4	18.0	18.6	....
Walleye									
Claytor Lake	254	8.1	13.9	18.4	22.6	25.5	27.4	29.8	32.2
Norris Reservoir (Stroud, 1949a)	....	10.3	16.4	18.7	19.9	20.8	21.0	22.1	24.9
White crappie									
Claytor Lake	200	2.6	5.3	8.0	10.5	12.0	13.7	16.1	....
Hiwassee Reservoir (Stroud, 1949b)	....	2.4	6.8	9.5	9.5	....	....	....	....
Bluegills									
Claytor Lake	150	1.5	3.5	6.0	7.7	8.5	9.6	....	....
Reelfoot Lake (Schoffman, 1938)	....	....	5.57	5.98	6.78	7.66	8.40	10.23	....
Largemouth bass									
Claytor Lake	48	4.5	10.1	13.6	15.7	16.8	17.8	....	....
Norris Reservoir (Stroud, 1948)	....	6.9	12.2	14.7	16.1	17.5	19.3	20.8	....
Yellow perch									
Claytor Lake	59	3.1	5.5	8.5	9.9	....	....	....	....
Connecticut waters (Webster, 1942)	....	3.7	6.0	7.8	9.0	9.9	10.6	11.2	....

[1] Estimates based on direct proportionality of increase in scale size to increase in length of fish.

percent return in 1948 and the same return in 1949. The smallmouth bass returns for 1948 and 1949 were 16 and 40 percent, respectively. Very little can be said concerning the largemouth bass return since only 6 of the 26 tags were returned during the 2-year period. Assuming that the tagged and untagged fish have been subject to the same fishing pressures, approximately 28 percent of the spotted bass were harvested from Claytor Lake in 1 year. The return of 40 percent of the smallmouth bass in 1949 appears to be high, but it is probably a valid indication of the extent of the harvest in the area of heavy fishing where most of the bass-tagging was conducted. Since the fishing pressure in this area was greater than the average pressure for the entire lake it is believed that the total harvest of this species during 1949 was nearer the 20 to 30 level. This level was probably attained also in 1948 although only 16 percent of the tags were returned.

The return of marked white crappie varied greatly in the 2 years of the study. In 1948, 17 percent were returned and in 1949 only 6 percent were recovered by anglers. This apparent reduction in harvest was explained when returns were broken down into size groups. In 1948, when all of the crappie tagged were caught by angling, the modal length of the fish was 10 to 12 inches. In 1949 when 320 of the 491 fish marked were captured in nets, the majority of the fish taken by nets were from 7 to 10 inches long. Although a total of 6 percent of the tagged crappie were recaptured in 1949, 13 percent of crappie above 11 inches and 4 percent below 11 inches were taken. Although large crappie were harvested at a higher rate than the smaller ones, the total harvest was considered to be low in comparison to the availability of the species. Only 47 walleye were tagged during 1948 and 83 during 1949. Recaptures made in 1948 were barely 6 percent but reached 14 percent in 1949. The number of walleye tagged was considered insufficient for an estimate of the harvest. However, the rate of harvest was probably below that of the basses.

A creel census was conducted on Claytor Lake during the fishing seasons of 1948 and 1949 to obtain a measure of the availability of the individual species. In 1948, census-takers were stationed at two docks, one on the upper part of the lake and the other on the middle section. A man also counted the fishermen on the lake from a motor boat. The station census-takers checked the creel every day from June 20 to June 27 and on each Saturday and Sunday from June 27 to July 31. Anglers were counted daily until June 27 and then on 3 days each week (Wednesday, Saturday, Sunday) until July 31. During the latter part of July, 1948, the fishing intensity was so low that the hiring of census-takers could not be justified. Therefore, after July 31 one man in a boat interviewed the fishermen on the lake and also made a total count of fishermen. This count was made on Wednesday, Saturday, and Sunday during August, September, and October and on Saturday and Sunday only during November. December weather prevented making more than three counts during the month. The census-takers recorded

TABLE 7.—*Number of fish tagged in Claytor Lake and the number and percentage of fish recaptured during 1948 and 1949.*

Species	1948			1949			Total		
	Tagged	Recaptured		Tagged	Recaptured		Tagged	Recaptured	
		Number	Percentage		Number	Percentage		Number	Percentage
Spotted bass	295	83	28	146	41	28	694	208	30.0
Smallmouth bass	56	9	16	171	69	40			
Largemouth bass	19	4	21	7	2	29			
White crappie	172	30	17	491	29	6	663	59	8.9
Walleye	47	3	6	83	12	14	130	15	11.5
Total	589	129	22	898	153	17	....	....	....

TABLE 8.—*Estimated number of days and hours of fishing and total catch during the 1948 fishing season on Claytor Lake.*

Item	June	July	August	September	October	November	December	Total
Fisherman count[1]	257	1,198	681	408	901	269	43	....
Number of days	771	3,594	2,043	1,224	2,703	807	129	11,271
Number of hours	3,855	17,970	10,215	6,120	13,515	4,035	645	....
Pounds of fish per hour	.114	.086	.072	.086	.14	.18	.20	....
Numbers of fish	439	1,545	735	526	1,892	726	129	6,004

[1] Estimated one-third of fishermen counted.

TABLE 9.—*Summary of catch of fish per hour of effort during the regular open fishing season (June 20 to December 31, 1948) and during pre-season angling conducted for tagging purposes on Claytor Lake.*

Item	Pre-season tagging	June 20-30	July	Aug.	Sept.	Oct.	Nov.	Dec.
Total fishermen checked	....	903	212	681	408	901	269	43
Total hours fished	2,299	1,882	1,482	1,432	1,147	2,235	840	115
Number of fish per hour	.26	.24	.31	.25	.22	.22	.41	.31
Pounds of fish per hour	....	.11	.086	.072	.086	.14	.18	.20

the following data on each group of fishermen: boat or shore fishing; number of men in a boat; number of hours fished; and number, length, and weight of each species of fish captured. In 1949 the weight of the fish was not recorded because it was considered desirable to expedite the counting of the fish when the anglers reached the dock. During the period June 20 to June 30, 1949, daily census-takers were stationed at three docks, one at the upper end, one at the middle, and the other at the lower end of the lake. After June 30 the creels were checked periodically at the three docks. A total count of fishermen was not conducted in 1949.

In 1949 the data were tabulated by regions of the lake and consist of the records of the census-takers who were located about 8 miles apart. It was assumed that the data at each station would give a good indication of the composition of the fish population in that vicinity in spite of the fact that fishermen during the first week of the 1949 fishing season trolled over as much as two regions of the lake.

At the close of the fishing season in 1948 it was estimated that 11,271 fishing days were spent on Claytor Lake with a resulting catch of 6,004 pounds of fish (Table 8). It was estimated that one-third of the fishermen were counted and that each fisherman angled for 5 hours. These estimates covered an area of about 3,500 acres. The annual harvest of sport fish was estimated to be 1.7 pounds per acre.

The creel census indicated that fishing was much better in 1949 than in 1948. Catch per unit of effort (number of fish per hour of fishing) ranged from a low of 0.22 to a high of 0.41 in 1948 (Table 9). This range appears narrow when numbers are considered. However, when interpreted by pounds per unit of effort, the range is much wider (0.072 to 0.20). In 1949 the catch per unit of effort expressed in numbers ranged from 0.13 to 0.60 (Table 10).

The fishing intensity during 1948 was highest in June and October and the fishing was considered the best during these periods (Table 11). The catch per unit of effort in June and October, 1948, was low with 0.24 and 0.22 fish, respectively. However, the catch in terms of pounds

TABLE 10.—*Summary of catch of fish per hour during the period of June 20 to July, 1949, in the upper, middle, and lower regions of Claytor Lake and during the pre-season angling for tagging purposes (April to June 20).*

	DATE							
	Pre-season tagging	June 20-27			June 27-July 31			June 20-July 31 Average
		Upper	Middle	Lower	Upper	Middle	Lower	
Total fishing hours checked	2,141	2,177	2,255	1,417	3,863	3,398	1,023	....
Fish per hour	0.24	0.60	0.20	0.44	0.53	0.13	0.135	0.32

per unit of effort was high with 0.11 and 0.14 for June and October as compared with a return of 0.072 pounds in August. The higher proportion of bass in the creel during June, October, and November was responsible for the increased fishing intensity during these months. The fishing returns in November and December were relatively high, but weather conditions prevented a high fishing intensity.

Angling was considered good during the pre-season tagging program in both years. The catch per unit of effort was 0.26 and 0.24 for 1948 and 1949 respectively (Tables 9 and 10). During periods of large yield there appeared to be a tendency for the returns per hour to be lower than would be expected. This drop may have resulted from the large number of inexperienced fishermen on the lake at this time. When the fishing was poor only the expert anglers participated, and average yield was consequently higher for those periods.

The results for 1949 (Tables 10 and 12) show the effect of pan fishing upon the catch per unit of effort. The high returns were in the upper region of the lake, where crappie were readily caught, and the low returns were in the middle section where bass and walleye comprised much of the take. Crappie fishing was important in the lower region and increased the returns. Few anglers fished for bluegills and catfish,

TABLE 11.—*The number of fish of each species recorded in creel census during the various months of the fishing season on Claytor Lake — 1948.*

Species	Month						
	June	July	August	September	October	November	December
Spotted bass	75	13	13	16	139	25	5
Smallmouth bass	15	3	1	4	51	4	1
Largemouth bass	10	1	....	1	16	4	1
Bass-unclassified	....	....	7	16	42	65	....
Walleye	57	16	10	22	119	2	....
White crappie	121	375	214	110	247	193	29
Bluegills	154	39	101	72	46	15	....
Channel cat	9	3	11	13	66	1	....
Carp	2	4	....	....	1	....	....
Yellow perch	....	....	....	....	5	7	....

TABLE 12.—*Number of fish of each species recorded in 1948 and 1949 creel census and summarized for 1949 in each region of the lake.*

	1948	1949			
	1948	Upper region	Middle region	Lower region	Total
White crappie	1,279	2,771	300	430	3,501
Bluegill	427	135	281	136	552
Channel catfish	103	100	57	10	167
Spotted bass	286	80	100	79	259
Smallmouth bass	130	34	47	213	294
Largemouth bass	33	9	21	40	70
Bass (unidentified)[1]	110	....	....	....	....
Walleye	126	209	102	64	375
Yellow perch	12	2	1	3	6
Carp	7	7	2	2	11
Flathead catfish	....	4	....	1	5

[1] Majority were spotted bass.

whereas survey collections revealed a heavy population of both species. Bluegill collected in poisoning experiments were more numerous than any other species of fish and gill-netting suggested a relatively high population of channel catfish. In 1948, 262 channel catfish were taken as compared with 310 bass and 216 walleye.

Population changes were noticeable in parts of Claytor Lake during the 1948 and 1949 fishing seasons. The spotted bass was the predominating species of black bass in all parts of the lake in 1948 with the smallmouth ranking second and the largemouth bass making a poor third (Tables 11 and 12). In 1949 the spotted bass was still the predominating bass species in the middle and upper reaches of the reservoir, but in the lower 6 miles of the lake the smallmouth had become predominant. The largemouth bass remained a weak third throughout 1949.

Another major population change was suggested by the fact that the white crappie was caught chiefly in the upper part of the lake during 1948, while in 1949 the anglers found them to be numerous in all parts of the reservoir. Here, as in other reservoirs,[1] the fish population is not static.

RESULTS OF PREVIOUS MANAGEMENT PRACTICES

The present investigation has shown that fish stocking from 1939 to 1946 did not appreciably affect the fish populations of Claytor Lake. The number of each species stocked (Table 2) was insignificant when compared to the existing fish population with the exception of the 12,040 adult yellowbelly sunfish and the 10,813 adult largemouth bass. The numbers of these species should have been sufficient to establish them in the lake if the habitat had been suitable, but no yellowbellies were taken in the collections and largemouth bass were rare. It must be concluded that stocking Claytor Lake with these species did not establish them. However, the stocking of adult fish of other species probably built up the fishable population faster than could have been expected from normal growth of indigenous populations. Closure of the fishing season in 1946, during the period from December 31 to June 20, did not harm the fishable population, but it did not permit the maximum harvest to be taken from the lake.

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[1] R. W. Eschmeyer — personal communication.

Proposed Fish Management Practices

Fishing Regulations.—Since the harvest of bluegill, white crappie, and channel catfish was low and it is believed that the harvest of walleye is also low, it has been recommended that a 12-months' open season be permitted for these species. Bass were subjected to a heavy fishing pressure and were harvested at a relatively high rate. However, because it appears that a greater harvest would be permissible, it has been recommended that the present season be extended so that only the spawning period between March 31 and June 1 remain closed to bass fishing.

Stocking Fish.—The fish productivity of a body of water may be increased by increasing the fertility of the water or by transforming any unutilized plants and invertebrate organisms into fish. Since the size of Claytor Lake prevents the practical application of fertilizer, better utilization of the existing plankton should be considered. The plankton is not now being utilized extensively by fish because the main fish-food cycle follows the pattern of littoral forms and zooplankton through forage fish to predaceous fish. R. W. Eschmeyer[1] attributes the relatively high production of Norris Reservoir to the plankton-shad-game-fish food cycle. The introduction of the gizzard shad (*Dorosoma cepedianum*) into Claytor should produce a more efficient food cycle and hence a higher fish production. It has been recommended that the stocking of gizzard shad be considered, but only after making further observations during 1950 and 1951 to determine shifts or changes in the fish population.

Continuing Investigations.—Since populations are not static, a limited annual or biennial fact-finding program is recommended. It should include: (1) creel census and harvest-rate studies to determine trends in the catch and degree of utilization; (2) population studies to determine changes in composition; and (3) continued fish-growth investigations to determine the adequacy of food supplies at existing rates of exploitation and population density.

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RESULTS OF STOCKING LARGEMOUTH BLACK BASS AND CHANNEL CATFISH IN EXPERIMENTAL TEXAS FARM PONDS

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Abstract

Twenty-two experimental farm ponds were operated at the A. E. Wood State Fish Hatchery, San Marcos, Texas, during the period 1948-50. Various stocking ratios and species combinations were employed for both fry and fingerlings of largemouth black bass (*Micropterus salmoides*) and fingerling channel catfish (*Ictalurus lacustris*). Forage fish including bluegill (*Lepomis macrochirus*), redear (*Lepomis microlophus*), and yellowbelly (*Lepomis auritus*) sunfish were used in these combinations. Black crappie (*Pomoxis nigromaculatus*) were stocked in two ponds. Ponds were compared on basis of pounds per acre per year. High production in total pounds of edible fish was not dependent on stocking ratio alone: 50 catfish, 100 bluegill, and 50 crappie per acre (152.4 pounds), 100 catfish only (116.2 pounds), 100 bass fingerlings and 1,500 bluegill (100.3 pounds), 100 bass fingerlings, 100 bluegill and 50 crappie (96.4 pounds), and 250 bass fingerlings only per acre (94.1 pounds) were high combinations. Fertilization increased the total production of edible fish in bass-bluegill combinations.

Yields from bass-bluegill ponds indicate that the weight of edible bass per acre is decreased as the stocking ratio of bluegill is increased. Average weight of adult bass was found to vary inversely with survival rate of fingerlings. Average weight of adult bluegill was found to vary inversely with number stocked. Results from bass-fry ponds indicate that ratios of 200 to 400 bass fry only per acre produce greatest weight of edible bass, but bass-fry-sunfish combinations produce bass with greater individual weights. Yields from all ponds suggest that channel catfish afford a higher poundage of edible fish per acre per year than any other species stocked.

Introduction

The various methods of stocking farm ponds described below were part of a larger program set up to determine proper procedures for securing maximum yield of edible fish from Texas farm ponds. Twenty-two ponds ranging in size from 0.07 to 2.53 acres were set aside at the A. E. Wood State Fish Hatchery, San Marcos, Texas, for these experiments. All of the ponds were supplied with water from the headwaters of the San Marcos River. The water, originating in limestone, is clear and hard and has a year-round pH of 7.2.

Fish normally stocked in Texas farm ponds were used to stock the experimental ponds. They include the largemouth black bass *(Micropterus salmoides)*, black crappie *(Pomoxis nigro-maculatus)*, bluegill sunfish *(Lepomis macrochirus)*, redear sunfish *(Lepomis microlophus)*, yellowbelly sunfish *(Lepomis auritus)*, and the channel catfish *(Ictalurus lacustris)*. All of the catfish ponds were stocked in November, 1948, with fingerlings and drained during the summer of 1950. Bass fingerling ponds were also stocked in November, 1948, and drained during the summer of 1950. The bass-fry ponds were stocked with advanced fry during April, 1949. Sunfish needed to complete the bass-fry ponds were added during November, 1949. Bass-fry ponds were drained during the summer of 1950.

Fourteen of the twenty-two experimental ponds were fertilized (as noted in the tables) with superphosphate (20 percent), 16-20-0, and 4-12-4 commercial fertilizer. Since no attempt was made to control aquatic plants, it was necessary to rake most of the ponds before they were drained. Many sunfish fry were lost during this operation, but the total weight lost was too small to influence the results significantly. When the ponds were drained, the fish were immediately sorted, measured, and weighed. All measurements were expressed as total length. The total production of all ponds during the period of observation was expressed in terms of pounds per acre per year without reference to number of months of operation.

PRODUCTION FROM PONDS STOCKED WITH BASS FINGERLINGS

Eight ponds were stocked with bass fingerlings in various combinations with bluegill sunfish and crappie fingerlings. One of the ponds was stocked with 250 bass only per acre; two were stocked with 100 bass and 1,500 sunfish per acre; two were stocked with 150 bass and 100 bluegill per acre; one was stocked with 125 bass and 1,000 bluegill per acre; one with 125 bass and 500 bluegills per acre; and one with 100 bass, 100 bluegill, and 50 crappies per acre (Table 1). The greatest total weights of edible fish per acre were obtained from ponds stocked with 100 bass and 1,500 bluegills per acre (100.3 pounds); 100 bass, 100 bluegills, and 50 crappies (96.4 pounds); and 250 bass only (94.1 pounds). One other pond had relatively high production (125 bass and 1,000 bluegill, yielding 71.4 pounds). In all but one pond stocked with bluegill the greater part of the total production was made up of bluegill.

The greatest total weight of edible bass per acre (94.1 pounds) was obtained when bass were stocked alone. Two other ponds had a relatively high production of edible fish. The ponds stocked with crappie yielded 46.2 pounds and the one with 150 bass and 100 bluegill produced 40.6 pounds.

The greatest harvest of edible bluegill was taken when 100 bass and 1,500 bluegill were stocked in a fertilized pond. This combination produced 75.0 pounds per acre. Three other ponds were comparatively high in production. The pond stocked with 125 bass and 1;000 bluegill produced 46.4 pounds of bluegill; the one with 100 bass, 100 bluegill,

TABLE 1.—*The yield, pounds per acre, survival, and growth of fish in eight farm ponds stocked with various ratios of bass, bluegill, and crappie fingerlings.*[1]

Stocking ratio (fish per acre)	Months operated	Fertilization[3] (pounds per acre)	Percentage survival	Average length at harvest (inches)	Average weight at harvest (ounces)	Production (pounds per acre)	
						Total	Edible fish[2]
250 bass	18	none	69.0	8.8	3.5	94.1	94.1
100 bass	16	100 superphosphate (1949)	77.7	9.3	5.4	25.3	25.3
1,500 bluegill		100 16-20-0 (1949)	23.8	6.6	3.5	183.2	75.0
		400 4-12-4 (1950)					
						208.5	100.3
100 bass	18	none	33.3	11.4	10.7	130.5	28.6
1,500 bluegill			3.0	7.1	5.0	109.1	11.7
						239.6	40.3
150 bass	18	100 superphosphate (1949)	42.9	10.6	9.3	57.5	40.6
100 bluegill		100 16-20-0 (1949)	64.4	7.5	5.7	191.4	20.0
		400 4-12-4 (1950)					
						248.9	60.6
150 bass	18	none	57.1	9.1	4.5	27.4	21.4
100 bluegill			33.3	7.0	4.3	117.4	7.6
						144.8	29.0
125 bass	18	none	83.3	8.9	4.2	25.0	25.0
1,000 bluegill			28.8	6.4	3.0	112.4	46.4
						137.4	71.4
125 bass	18	none	83.3	9.3	4.9	29.1	29.1
500 bluegill			35.4	6.5	3.5	118.1	35.3
						147.2	64.4
100 bass	19	100 superphosphate (1949)	47.1	11.8	12.8	50.2	46.2
100 bluegill		100 16-20-0 (1949)	16.0	8.0	8.0	97.8	41.8
50 crappie		400 4-12-4 (1950)	52.7	9.0	8.0	8.8	8.4
						156.8	96.4

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[1] Fingerling bass, 4 to 5 inches in length; sunfish, 1 to 1½ inches; crappie, 2 to 3 inches.

[2] Edible fish includes fish of following minimum lengths and larger: bass. 7 inches; sunfish, 5 inches; crappie, 7 inches.

[3] Date when fertilizer was added.

and 50 crappie produced 41.8 pounds; and the one with 125 bass and 500 bluegill produced 35.3 pounds. The second pond of the latter group was fertilized.

Yields from the experimental ponds (Table 1) indicate that as the ratio of bluegill to bass is increased, the total weight of edible bass per acre per year is usually decreased and the total weight of edible bluegill is usually increased. The total weight of all edible fish showed no trend. Swingle (1949) concluded that although bluegill appeared to be the most desirable forage fish to stock with bass, they did not yield the highest bass production in short-time experiments.

From results obtained with different stocking ratios, it appears that the survival rate of the bass fingerlings influences the size of the edible bass to a greater extent than the stocking ratio or species combination. The average weight of the adult bass varies inversely with the survival rate of the bass fingerlings. Since this relationship exists, low survival rates do not seem to influence the total production of edible bass.

The average weight of the edible bluegill at the time of harvest varies inversely with the stocking ratio. Surber (1949) also found that the average size of bluegills varied inversely with the number stocked. Ball (1949) stated that fertilization produces greater yields in ponds stocked with bass-bluegill combinations. In the present study it is apparent, from a comparison of the two ponds stocked with 100 bass and 1,500 bluegill and the two ponds stocked with 150 bass and 100 bluegill per acre, where one pond in each group was fertilized, that fertilization increased the total production of edible fish.

Production from Ponds Stocked with Bass Fry

Ten ponds were stocked with bass fry in various combinations with bluegill, redear, and yellowbelly sunfish fingerlings (Table 2). In these experiments, the greatest production of edible fish was secured with stocking ratios of 400 bass fry only per acre (62.4 pounds), 100 bass fry and 1,000 yellowbelly sunfish (60.9 pounds), and 100 bass fry and 1,000 bluegill (59.5 pounds). These yields are lower than those taken from the bass fingerling ponds. The greatest weight of edible bass per acre was obtained with stocking ratios of 400 bass only (62.4 pounds), 200 bass and 25 redear sunfish (44.8 pounds), and 200 bass only (41.1 pounds). The average weight of edible bass per acre produced by the fry ponds is approximately equal to that produced by the bass fingerling ponds. Total weight of edible redear sunfish per acre was very low (1.9 and 2.3 pounds). This low production may have resulted from low stocking ratios (25 and 100 per acre) and the low survival rate in one case (22.6 percent). It was noted that the redear spawned in only two of the four stocked ponds and produced only a few hundred fry, approximately ½ inch in length. Since many of the

TABLE 2.—*The yield in pounds per acre, survival, and growth of fish in 10 farm ponds stocked with various ratios of bass fry, redear, bluegill, and yellowbelly sunfish fingerlings.*[1]

Stocking ratio (fish per acre)	Number ponds	Months operated	Fertilization[3] (pounds per acre)	Percentage survival	Average length at harvest (inches)	Average weight at harvest (ounces)	Production (pounds per acre)	
							Total	Edible fish[2]
400 bass	2	14	100 superphosphate (1949) 100 16-20-0 (1949) 400 4-12-4 (1950)	74.5	8.2	4.0	76.2	62.4
200 bass	2	14	100 superphosphate (1949) 100 16-20-0 (1949) 400 4-12-4 (1950)	85.3	8.8	4.7	50.3	41.1
200 bass	2	15	100 superphosphate (1949) 100 16-20-0 (1949) 400 4-12-4 (1950)	61.6	9.8	7.2	69.3	44.8
25 redear				61.1	5.3	2.4	1.9	1.9
							71.2	46.7
150 bass	2	15	100 superphosphate (1949) 100 16-20-0 (1949) 400 4-12-4 (1950)	64.6	9.3	6.1	56.3	30.6
100 redear				22.6	5.1	2.5	2.5	2.3
							58.8	32.9
100 bass	1	15	100 superphosphate (1949) 100 16-20-0 (1949) 400 4-12-4 (1950)	64.4	10.9	10.0	74.5	32.6
1,000 yellowbelly				29.8	5.3	1.9	35.2	28.3
							109.7	60.9
100 bass	1	14	100 superphosphate (1949) 100 16-20-0 (1949) 400 4-12-4 (1950)	72.0	9.9	7.2	49.1	27.6
1,000 bluegill				24.7	5.8	2.3	52.4	31.9
							101.5	59.5

[1] Bass fry, ¾ to 1 inch in length; sunfish 1 to 1½ inches in length.

[2] Edible fish includes fish of following minimum lengths and larger: bass, 7 inches; sunfish, 5 inches.

[3] Dates in parentheses indicate time of application.

adults were in spawning condition when captured, it is possible that redear spawn late and very moderately their first year in contrast to bluegill sunfish which produce great numbers of fry under the same conditions.

Production from the one pond stocked with yellowbelly sunfish amounted to 28.3 pounds of edible yellowbelly per acre. However, fish averaging 5.3 inches in length had an average weight of only 1.9 ounces. One pond stocked with 100 bass and 1,000 bluegill had a moderate production of 31.9 pounds of edible bluegill per acre, but the edible bass production was the lowest of all of the bass fry ponds.

The survival rates of the bass fry ranged from 61.6 to 85.3 percent, but average weight of the edible bass was not greatly influenced by the survival rate of the fry (Table 2). The highest average weights for edible bass were taken from ponds stocked with 100 bass fry and 1,000 yellowbelly per acre (10.0 ounces), 200 bass and 25 redear (7.2 ounces), and 100 bass and 1,000 bluegill per acre (7.2 ounces). Ponds stocked with bass fry only produced large weights of edible bass per acre, but the average weights of these fish were the lowest of all ponds stocked with bass fry. This result seems to indicate that a high production of edible bass from bass fry can best be obtained when 200 to 400 bass fry only per acre are stocked. It also suggests that a bass fry-sunfish combination should be used to produce bass with higher individual weights. Since all ponds were fertilized, no strict comparisons can be made with the fingerling experiments.

PRODUCTION FROM PONDS STOCKED WITH CHANNEL CATFISH FINGERLINGS

Three ponds (0.07 acre each) were stocked with channel catfish fingerlings only at the rate of 50, 75, and 100 fish per acre respectively. One other pond (2.53 acres) was stocked with 50 channel catfish, 100 bluegill, and 100 crappie per acre (Table 3). The greatest production per acre was obtained from the pond stocked with 50 catfish, 100 bluegill, and 100 crappie per acre (152.4 pounds). The pond stocked with 100 catfish only had a good production (116.2 pounds per acre) but was found to contain 111 small bluegill and warmouth bass (2 to 4 inches) which entered through the water supply. Only the pond in which bluegill and crappie were stocked was fertilized. The weights of edible fish per acre produced in these two ponds were the highest obtained in the 22-pond series.

The highest production of edible catfish was obtained by stocking 100 catfish only per acre (116.2 pounds). The ponds stocked with 50 and 75 catfish only per acre yielded 77.3 and 81.3 pounds, respectively. This production was very high when compared with individual productions from bass or bluegill. All three of these catfish yields are higher than the total production in weight of any other species in the 22-pond

TABLE 3.—*The yield in pounds per acre, survival, and growth of fish in four farm ponds stocked with various ratios of channel catfish fingerlings, and bluegill and crappie fingerlings.*[1]

Stocking ratio (fish per acre)	Months operated	Fertilization[3] (pounds per acre)	Percentage survival	Average length at harvest (inches)	Average weight at harvest (ounces)	Production (pounds per acre)	
						Total	Edible fish[2]
50 catfish........	18	none	80.0	18.9	33.0	77.3	77.3
75 catfish........	18	none	75.0	16.3	23.0	81.3	81.3
100 catfish........	18	none	90.0	15.9	22.0	116.2	116.2
50 catfish........	21	100 superphosphate (1949)	47.3	19.1	38.0	55.4	55.4
100 bluegill.......	....	100 16-20-0 (1949)	43.2	6.9	4.8	151.9	86.7
100 crappie.......	....	400 4-12-4 (1950)	30.5	9.3	8.4	30.3	10.3
						237.6	152.4

[1] Catfish fingerlings, 4 to 5 inches in length; sunfish, 1 to 1½ inches; crappie, 2 to 3 inches.
[2] Edible fish includes fish of following minimum lengths and larger; catfish, 9 inches; sunfish, 5 inches; crappie, 7 inches.
[3] Dates in parentheses indicate time of application.

series, with the exception of bass in the pond stocked with 250 bass fingerlings per acre only (94.1 pounds).

The pond stocked with 50 catfish, 100 bluegill, and 100 crappie per acre produced 55.4 pounds of edible catfish per acre but more than half of the total weight of edible fish produced was in bluegill. The lower weight of edible catfish produced was probably a reflection of its low survival rate (47.3 per cent). The survival rates of the catfish in the other ponds were 75, 80, and 90 percent, respectively. Results from these experiments seem to indicate that the stocking ratio of channel catfish greatly influences the average weight as well as the total weight of edible catfish produced. The average weight varies inversely with the stocking ratio and the total weight varies directly with the stocking ratios. It therefore appears that highest total weight of edible catfish can be obtained from stocking 100 fingerlings per acre. To obtain larger fish and still retain a high total weight of edible fish, 50 fingerlings per acre give the best results. From the limited experiments in which crappies were used, it does not appear that this species will produce much edible fish under the conditions existing in these ponds.

Consideration of all results shows that channel catfish produce a greater yield per acre per year, regardless of stocking ratios, than any other species of fish used in the 22 ponds. The foregoing experiments also indicate that the type of management required for farm ponds in Texas will depend upon whether large production, large fish and low production, or some intermediate result is desired.

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EXPERIMENTS WITH VARIOUS RATES OF STOCKING BLUEGILLS, *LEPOMIS MACROCHIRUS* RAFINESQUE, AND LARGEMOUTH BASS, *MICROPTERUS SALMOIDES* (LACÉPÈDE), IN PONDS

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Abstract

Results from stocking adult bluegills and largemouth bass, fingerling bass and adult bluegills, and fingerling bluegills and fingerling largemouth bass are compared. Increase in rates of stocking bluegills from 8 to 1,500 per acre in bluegill-bass combinations gave corresponding increases in pounds of harvestable fish per acre and corresponding decreases in the cost per pound. The calculated A_T value (percentage harvestable fish) could be used to predict the success of various stocking rates. Unbalanced populations resulted from stocking with insufficient numbers of either largemouth bass or bluegills. When normally adequate numbers of each species were stocked, unbalanced populations occasionally resulted from extremely high mortality among the stocked fish. Where no fish were removed by fishing, an average of 25.6 percent of the stocked bass died during the first 6 months and an additional 20.4 percent during the following year; similarly an average of 15.4 percent of the stocked bluegills died during the first year and an additional 19.1 percent during the second year.

Introduction

The objective of various methods of stocking ponds with a combination of bluegills, *Lepomis macrochirus* Rafinesque, and largemouth black bass, *Micropterus salmoides* (Lacépède), is to establish fish populations from which it will be possible subsequently to harvest satisfactory annual crops of fishes. Such a population has been defined as a "balanced population" and is characterized by (Swingle, 1950): (1) a definite range in ratio (F/C) of weight of all forage fishes to the weight of all piscivorous fishes. The range in balanced populations is $F/C = 1.4$ to 10.0, and the most desirable range is $F/C = 3.0$ to 6.0; (2) a narrow range in the ratio (Y/C) of the weight of small forage fishes to the total weight of piscivorous fishes. The range in balanced populations is $Y/C = 0.02$ to 5.0, and the desirable range is $Y/C = 1.0$ to 3.0; (3) more than 40 percent (A_T value) of the total weight of the population in the form of fish of harvestable size. The desirable range is $A_T = 60$ to 85; (4) at least 18 and preferably more than 35 percent (A_F value) of the total weight of bluegills in the form of harvestable bluegills. These requirements for balanced populations obviously limit the stocking methods that may be used to obtain such results. Three principal methods of stocking appear possible.

One method is to stock small numbers of adult or fingerling largemouth bass and bluegills, and to depend upon subsequent reproduction and predation to yield the correct numbers of each species. This method usually requires 2 or more years to establish a balanced population and would appear somewhat uncertain, as its success depends upon two variables, reproduction and predation, in two species of fishes.

A second method is to stock approximately 100 largemouth bass fry or fingerlings per acre and a small number of adult or fingerling bluegills. In this case, reproduction of and subsequent predation upon the latter species must furnish the correct number of bluegills to satisfy the requirements for balance.

The third method requires that the correct number of small bluegills and small bass be stocked so that 1 year later the weights of those which are still living will satisfy the A_T and A_F requirements and at the same time establish a desirable F/C ratio. Methods of calculating the numbers required for stocking when the carrying capacity of the pond is known are described elsewhere (Swingle, 1950). For example, the numbers recommended for stocking ponds in the Southeast (Swingle and Smith, 1940, 1942; Smith and Swingle, 1943) were 100 largemouth bass fry or fingerlings and 1,000 to 1,500 bluegill fingerlings per acre for fertilized ponds where the carrying capacity was determined to be between 300 and 500 pounds per acre. These recommendations have been checked in numerous experiments during the last 12 years and have been reasonably satisfactory in general usage. Balanced populations usually result in 1 year but do not, however, result invariably for reasons to be discussed later.

Experiments at the Alabama Agricultural Experiment Station dealing with these various methods of stocking will be reported and discussed in this paper.

STOCKING WITH ADULT FISH

Several experiments in which a pond was stocked with adult bluegills, adult largemouth bass, and other species were reported (Swingle and Smith, 1940, 1943a, b) to have failed because in such a combination there was no food for large adult bass. Consequently these fish failed to produce eggs the first year. In subsequent years they also failed because the pond was overcrowded with bluegills, crappie, *Pomoxis annularis* Rafinesque, and catfish, *Ameiurus natalis* (LeSueur).

In other experiments, it was found that young 6- to 8-ounce largemouth bass obtained enough food from insects and tadpoles to spawn successfully in every test whereas large adults lost weight on such a diet and failed to spawn. Consequently, it was decided to try adult stocking again, using largemouth bass averaging slightly less than 0.5 pound.

A 1.6-acre unfertilized pond was stocked with 10 largemouth bass (6 to 8 ounces each) in the winter. After they spawned successfully during the following April, 12 adult bluegills (0.3 pound each) were added. These bluegills spawned several months later and the young bass reduced the numbers of young bluegills to a level which was apparently correct for adequate stocking of the pond. During the following summer 122 bluegills weighing 33.9 pounds and 34 largemouth bass weighing 15.3 pounds, a total of 30.7 pounds of fish per acre, were caught. At the end of that year, the pond was drained and the following fishes recovered:

42	large largemouth bass	40.5 pounds
115	small largemouth bass	21.0
392	large bluegills	86.0
562	intermediate bluegills	29.0
22,451	small bluegills	78.5
27	large yellow bullheads	12.0
	Total	267.0

Population values: $F/C = 3.3$; $Y/C = 1.3$; $A_T = 52.0$

This population showed a desirable balance. The only drawback was that the bass caught during the second summer had an average weight of 0.45 pound and would have been too small to harvest in states having legal lengths of 11 or more inches. At the same time they were too large to have been thinned by predation and their removal was necessary to allow those remaining to grow to a more desirable size.

Because adult stocking has given general unfavorable results no additional experiments have been conducted with this method. The stocking rate in this experiment was approximately 5 largemouth bass (6 to 8 ounces each) plus 7 adult bluegills (4 ounces each) per acre. If additional experiments should prove that such a method of stocking could produce as desirable results as the present method of stocking with fingerling bluegill and advanced fry or 1-inch fingerling largemouth, the inability to sex largemouth bass accurately would bar its use in ponds of 1 acre or less. Unless lower rates of stocking could be used in large ponds, the problem of producing sufficient 6-ounce largemouth bass and 4-ounce bluegills in hatcheries for stocking any considerable acreage of ponds would be a much more difficult one than production of sufficient fingerlings to stock the same acreage at rates of 100 bass and 1,000 to 1,500 bluegills per acre.

STOCKING WITH LARGEMOUTH FINGERLINGS AND ADULT BLUEGILLS

To determine whether hatchery production and distribution of bluegills could be avoided, 100 largemouth bass fingerlings (1-inch) and 3 adult bluegills per acre were stocked in fertilized ponds. A 3.5-acre pond containing no cover and a 2.1-acre pond containing logs and stumps for cover were stocked with this combination. Assuming a carrying capacity of 350 pounds per acre, the calculated A_T value at the end of 1 year should have been approximately 20.3, indicating an unbalanced population. Seining during the second summer showed that bass had spawned in the pond without cover but had failed to spawn in the one with cover. The bluegills in both ponds had failed to reproduce, indicating unbalance and an overcrowded bluegill population as would have been expected from the calculated A_T value. Consequently, fishing was prohibited in both ponds for an additional summer to continue heavy predation pressure on the bluegills and to bring the A_T value of the populations into the balanced range. A heavy hatch of both bass and bluegills at the beginning of the third summer in the pond without cover indicated that a balanced population had been obtained. Failure of both bass and bluegills to reproduce in the pond containing cover continued the unbalanced condition in that pond. Both ponds were opened to fishing during the third summer. The catch per acre on each was as follows:

Species	Pond with cover Pounds	Pond without cover Pounds
Bluegills	8.9	56.0
Largemouth bass	28.3	70.0
Total catch per acre	37.2	126.0

After this initial catch of large fish in the pond with cover, no more fish of desirable size could be caught and the pond was drained. The population values were found to be $A_T = 18.6$, $F/C = 6.6$, and $Y/C = 5.8$, all indicative of an unbalanced condition. The pond without cover continued to give good fishing the following year with a catch consisting of 182.0 pounds of bluegills and 74.3 pounds of bass, or a total of 256.3 pounds per acre. The catch in these ponds substantiated the conclusion that with this method of stocking, largemouth bass could not reduce the young bluegills sufficiently to achieve balance except in the absence of cover even when no largemouth bass were removed until the third summer after stocking.

It appeared probable, however, that the problem of overcrowding by bluegills could be solved by originally stocking with more bass to insure adequate predation. Consequently, a 6-acre pond containing heavy brush cover in approximately one-half the pond area was stocked in June with 5 adult bluegills (average weight 3.5 ounces), 1 adult shellcracker (or redear) *Lepomis microlophus* Gunther, and 200 largemouth fingerlings (1-inch) per acre. The following November this pond was drained and the following fish were recovered:

730 large bluegills	144.8 pounds
3 shellcrackers	1.8
561 largemouth bass	65.5
Total	212.1

The bass had controlled adequately bluegill reproduction so that the survivors had grown to an average size of 0.20 pound. However, the bass were so overcrowded that their average size was only 0.12 pound, and no small bluegills were left for forage. Furthermore, overcrowding permitted a build-up of only 35.3 pounds per acre in a pond with a carrying capacity of 300 pounds per acre. For these reasons this method of stocking was considered to be a failure.

TABLE 1.—*Production of fish in 2-year experiments on rates of stocking bluegills in bluegill-largemouth bass combinations where 100 bass fingerlings were stocked per acre.*

Stocking rate per acre	Pounds recovered per acre						Ar Values	Balance	Average pounds per acre
	Largemouth bass		Bluegills			Total			
	Large	Small	Large	Intermediate	Small				
8 Bluegill adults	84.0	0.0	4.2	28.8	308.8	425.8	20.7	No	
8 Bluegill adults	45.0	26.2	5.0	8.8	216.8	301.8	16.6	No	
8 Bluegill adults	39.0	0.0	12.2	8.2	285.5	344.9	14.8	No	357.5
100 Bluegill fingerlings	54.5	0.0	8.0	55.0	354.2	471.7	13.2	No	
100 Bluegill fingerlings	52.0	0.2	9.0	7.2	350.0	418.4	14.6	No	
100 Bluegill fingerlings	65.0	23.0	179.0	30.0	53.5	350.5	69.6	Yes	413.5
248 Bluegill fingerlings	91.0	3.8	55.0	18.0	312.4	480.2	30.4	No	
248 Bluegill fingerlings	62.0	0.0	69.5	16.2	301.8	449.5	29.3	No	
248 Bluegill fingerlings	70.5	18.5	127.0	24.8	170.2	411.0	48.1	Yes	446.9
500 Bluegill fingerlings	95.2	0.0	34.5	29.0	276.0	439.3[1]	29.5	No	
500 Bluegill fingerlings	75.5	4.5	63.3	16.0	228.2	387.5	35.8	Doubtful	
500 Bluegill fingerlings	76.0	11.2	197.2	22.0	87.2	393.6	69.4	Yes	406.8
748 Bluegill fingerlings	124.0	7.0	60.5	3.0	269.0	463.5	39.8	Yes	
748 Bluegill fingerlings	50.0	10.2	138.3	48.2	126.8	373.5	50.4	Yes	
748 Bluegill fingerlings	98.5	3.8	74.5	38.5	186.3	401.6	43.1	Yes	412.9
1,000 Bluegill fingerlings	45.0	4.3	119.2	46.2	299.3	514.0	31.9	No	
1,000 Bluegill fingerlings	123.5	31.2	125.5	8.0	91.2	379.4	65.6	Yes	
1,000 Bluegill fingerlings	120.0	8.5	76.0	6.5	115.8	326.8	60.0	Yes	406.7
1,500 Bluegill fingerlings	28.0	7.0	294.0	4.0	53.0	386.0	83.4	Yes	
1,500 Bluegill fingerlings	47.0	7.0	193.0	0.0	103.0	350.0	68 6	Yes	368.0

[1] Includes 4.5 pounds small warmouth, *Chaenobryttus coronarius* (Bartram).

TABLE 2.—*Average production of harvestable fish and cost of fertilizer per pound of fish with different stocking rates of bluegills.*

Stocking per acre		Harvestable fish	
Bluegills	Largemouth Bass	Pounds per acre	Cost per pound, Cents
1,000	0	57.8	93.7
0	100	81.0	65.9
8	100	63.1	84.6
100	100	122.5	43.7
248	100	158.3	33.8
500	100	180.6	29.7
748	100	181.9	29.4
1,000	100	203.1	26.2
1,500	100	280.6	19.1

Numbers of bass intermediate between 100 and 200 per acre may have given better results. However, since amount of cover influenced the success of this method, and the relative percentages of deep and shallow water in ponds would probably affect predation, stocking requirements would be expected to vary for each individual pond. This does not appear to be a practical method for general use.

STOCKING WITH FINGERLING FISH

Stocking with the correct numbers of small bluegills and largemouth bass to achieve balanced populations is widely practiced throughout the United States. The correct numbers are dependent upon the carrying capacity of the water to be stocked (Swingle, 1950) and are calculated for the average mortality expected within 1 year. In order to obtain additional information on the effect of various rates of stocking, a series of 18 ponds, each having a surface area of 0.25 acre and an average depth of 4 feet, were uniformly fertilized to give an average carrying capacity of approximately 400 pounds of fish per acre.

Ponds in triplicate were stocked on December 1, 1947, with 8, 100, 248, 500, 748, and 1,000 bluegill fingerlings per acre. On May 3, 1948, 100 largemouth bass fingerlings (1-inch) per acre were added to each pond. Because it had been found previously that lower rates of stocking with bluegills usually required approximately two summers to produce balanced populations, the experiment was continued until October 6, 1949, when all ponds were drained and the populations counted and weighed. The results of these experiments, together with two similar 2-year experiments conducted in 1943-44 with 1,500 bluegills plus 100 bass per acre, are shown in Table 1.

It is of interest to compute the average cost of fertilization per pound of the harvestable (large) fish produced by the various rates of stocking and recovered upon draining the ponds. For purposes of comparison, the results from a 2-year experiment with two ponds stocked with largemouth bass only and with three ponds stocked with bluegills only are included (Table 2).

TABLE 3.—*Differences between calculated A_T values and the mean A_T values of 3 tests.*

Stocking rate	Calculated A_T	Mean A_T	Standard deviation of means	Mean-Calculated A_T difference
8 bluegills + 100 largemouth bass	18.1	17.4	± 1.7	— 0.7
100 bluegills + 100 largemouth bass	22.5	32.5	±18.5	+10.0
248 bluegills + 100 largemouth bass	30.0	35.9	± 6.1	+ 5.9
500 bluegills + 100 largemouth bass	42.5	44.9	±12.4	+ 2.4
748 bluegills + 100 largemouth bass	55.0	44.4	± 3.1	—10.6
1,000 bluegills + 100 largemouth bass	67.5	53.5	± 8.1	—14.0
1,500 bluegills + 100 largemouth bass	90.2	76.0	± 7.4	—14.2

The average production of harvestable fish per acre increased and the cost per pound decreased with increase in the rates of stocking bluegills up to 1,500 per acre in a bluegill-bass combination. Stocking with 100 bass only produced more usable fish than stocking with bluegills only, but both methods were extremely inefficient in the production of usable fish. It must be pointed out that since the experiment ran 2 years, the cost per pound was abnormally high as harvest is usually begun at the end of the first year. During the second year a considerable number of large fishes could normally be expected to die unharvested.

While production of large numbers of harvestable fish is one criterion of a successful method of stocking, a balanced population also must be established if good fishing is to continue after the original crop of large fish is removed.

The necessity for stocking adequate numbers of largemouth bass to prevent overcrowded bluegill populations and to establish balance is generally recognized (Bennett, 1943; Toole, 1947). The limits of the A_T and the A_F values in balanced populations previously discussed point out an additional cause of unbalance. Stocking too few bluegills can cause overcrowded bluegills in bass-bluegill populations during the second summer, and may cause permanent unbalance unless corrective measures are employed.

For the combinations used in these experiments, it is possible to compute the A_T value that might be expected normally to result by the beginning of the second summer and to predict the combinations that would be successful if average mortality occurred among the stocked fishes. The calculated A_T values were derived by assuming that 80 percent of the bluegills that were stocked would survive to reach an average size of 4 ounces at the beginning of the second summer, while 70 percent of the bass would survive to reach an average weight of 1 pound. The combined weight of the estimated surviving fishes was divided by 400 (the carrying capacity of the ponds in pounds per acre) and multiplied by 100 to give the calculated A_T values (Table 3). For comparison, the mean A_T values from three tests with each stocking rate are included.

The calculated A_T values represented conditions expected at the beginning of the second summer after stocking and the mean A_T values were the average of those found in three ponds the following October. It is evident that the calculated A_T value did foretell approximately the average results to be expected. The calculated A_T values indicated that at the beginning of the second summer ponds stocked with 100 bass plus 8, 100, or 248 bluegills would contain unbalanced populations. Seining samples during June and July of the second summer showed that eight of the nine ponds were overcrowded with bluegills. When the ponds were drained that fall, one additional pond had come into balance, and the other seven remained unbalanced in spite of continued predation during the second summer. One pond of the three stocked with 100 bluegills and 100 bass had a very light hatch of bluegills in July of the first summer. Bass apparently thinned this first hatch to the correct number for stocking, and it was in balance throughout the second year. When drained, it was found to contain 1,176 large bluegills per acre.

The stocking rate of 500 bluegills plus 100 bass per acre had a calculated $A_T = 42.5$, just above the minimum satisfactory value of 40. One pond produced a balanced population, one a population intermediate between balance and unbalance ($A_T = 35.8$), and one an unbalanced population.

Higher rates of stocking, from 748 to 1,500, bluegills plus 100 largemouth bass per acre would be expected from the calculated A_T values to yield balanced populations. Only one of the eight, with a stocking rate of 1,000 bluegills plus 100 bass per acre, failed to do so. In this pond the survival of the stocked bass was only 32 percent and unbalance apparently resulted from this cause.

In most of these experiments excessive natural mortality of bass occurred in unbalanced populations. A regression coefficient of $b = .957$ pound harvestable fish per each 1 percent survival of stocked bass was calculated, but the significance of this value could not be demonstrated (Snedecor, 1946). There was, however, significance at the 1 percent point for the effect of rates of stocking bluegills on production of harvestable fish.

There appeared to be a superficial relationship in these results between survival of bass and rates of stocking bluegills. A regression coefficient of $b = + 0.16$ was calculated, but was not significant at the 5 percent level.

PROBLEMS INVOLVED IN VARIABLE MORTALITY

Results in the experiments previously discussed showed that balanced populations usually resulted from stocking the calculated numbers of bluegills and bass necessary to produce A_T values and F/C ratios in the balanced range. While the average results appear to be encouraging, the variations in production within treatments are not so satisfactory (Table 1). They appear, however, to be the normal variations which are encountered in experiments on fish production. An analysis of all experiments conducted at this Station leads to the conclusion that the principal cause of differences in ponds receiving the same treatment was variation in the survival rates of the stocked fish.

The percentage survival of largemouth bass in comparable experiments at the end of the first 6 months after stocking with various rates of bass in bass-bluegill combinations is summarized in Table 4. The average survival for the standard stocking rate of 100 bass per acre was 74.4 percent (standard deviation of ± 13.6 percent) and for all rates was 66.5 percent, but the range was from 18.9 to 100 percent. In all cases the bass were handled carefully, accurately counted, transported only a short distance (usually less than 1 mile), reexamined, and all weakened individuals replaced before the ponds were stocked. Therefore, it must be assumed that the observed variations in survival are caused by differences in natural mortality.

TABLE 4.—*Percentage survival of largemouth bass in ponds with bass-bluegill combinations 6 months after stocking as 1-inch fingerlings in May.*

Year	Number experiments	Number stocked per acre	Percentage survival	
			Average	Range
1943	13	150	75.6	53.0–100.0
1944	4	100	83.0	72.0– 96.0
1944	16	148	45.9	18.9– 73.0
1946	5	100	64.8	52.0– 92.0
	1	120	50.0	
	1	240	61.6	
1947	9	100	76.0	60.0– 92.0
	2	48	95.8	91.8–100.0
1945	16	120	68.3	36.7– 96.7
Total or average	67		66.5	

Further light is shed on this problem by consideration of the survival of largemouth bass in 29 two-year experiments (Table 5). In these experiments the bluegills were stocked in November-December and largemouth bass fingerlings (1-inch) were stocked the following May. All ponds were drained in October-November of the following year, or approximately 18 months after the bass were stocked. While the average survival with the standard stocking rate of 100 bass per acre was 54 percent (standard deviation of ± 18.5 percent) and from all methods of stocking was 54.3 percent, the range was extremely variable, extending from 24.0 to 92.0 percent.

The mortality rate for the standard stocking rate of 100 bass per acre may be summarized as follows:

Period after stocking bass	Percentage mortality maximum	minimum	average
6 months	48.0	4.0	25.6
18 months	76.0	8.0	46.0
Difference (second year)			20.4

It appears that, when there is no fishing, on the average 25.6 percent of the stocked bass may be expected to die within the first 6 months and an additional 20.4 percent during the following year.

TABLE 5.—*Percentage survival of largemouth bass in ponds with bass-bluegill combinations 18 months after stocking as 1-inch fingerlings in May.*

Year	Number experiments	Number stocked per acre	Percentage survival	
			Average	Range
1942–43	3	100	62.0	40.0–92.0
	1	200	44.0	
1943–44	1	100	44.0	
	1	150	61.3	
	1	200	56.0	
	1	400	64.0	
1948–49	21	100	53.3	24.0–84.0
Total or average	29		54.3	

Similarly bluegill mortalities for all rates of stocking were as follows:

	Percentage mortality		
Period after stocking bluegills	maximum	minimum	average
11 months	77.1	0.0	15.4
23 months	76.0	0.0	34.5
Difference (second year)			19.1

Where no bluegills are removed by fishing, approximately 15.4 percent of the stocked fish on the average may be expected to die during the first year and an additional 19.1 percent during the second year.

It should be pointed out that the mortality during the second year produces variable results in 2-year experiments, but is otherwise relatively unimportant unless it is excessive. It merely replaces or supplements fishing as a method of removal of adult fishes.

Mortality during the first year after stocking, however, is extremely important as it must be estimated in calculation of the correct numbers for stocking. Extreme variations below the average survival figure are responsible for the failure of many ponds to achieve balance. Variations above the average cause differences in total production and average size but do not prevent the achievement of a balanced condition within the population. The most serious problem is that of variations in mortality among the stocked bass prior to their reproduction. It is during this period that excessive mortality may prevent adequate predation and cause unbalanced populations.

The most probable cause of excessive variation from the mean mortality of bass would appear to be either cannibalism among the stocked bass or predation by the bluegills. Predation among young bass may be largely prevented as long as adequate food for rapid growth is available. However, in the methods used for stocking ponds in the Southeast, bluegill fingerlings are added in the fall or winter and largemouth bass advanced fry or fingerlings (1-inch) are added the following spring. The small bass must compete with the stocked bluegills for food until the latter reproduce. This period of competition usually lasts from 1 to 2 months.

After the first hatch of bluegills the bass feed largely upon small fish and compete to a minor extent with large bluegills.

Various experiments were run in an attempt to determine some of the causes of mortality among stocked bass (Table 6). Stocking with large bluegills (average 1.5 ounces) 5 months prior to stocking bass resulted in an average bass survival of 62 percent as compared to a survival of 86 percent where smaller bluegills (average 0.14 ounce) were used. Since large bluegills would be expected to have a higher demand for food than small ones, these results might suggest that competition for food between these species was the major cause of high mortality of bass. However, where no bluegills were present, the average survival of bass was 76 percent, an intermediate value. It appears that factors

TABLE 6.—*Experiments with factors affecting largemouth bass survival in bluegill-bass combinations.*

Experiment	Stocking rate per acre[1]		Percentage survival of bass	Total pounds fish per acre
	Bluegills	Largemouth bass		
1	1,500 (large)	100	60.0	259.7
2	1,500 (large)	100	64.0	305.5
3	1,500 (small)	100	84.0	282.7
4	1,500 (small)	100	88.0	282.2
5	0	100	76.0	40.0
6	0	100	76.0	26.8
7	1,500	100	92.0[2]	671.2
8	1,500	100[3]	68.0	301.9
9	1,500	100[3]	76.0	343.2

[1] Bluegills were stocked November 29, 1946, and averaged 1.5 ounces in experiments 1 and 2. The average size in the remaining experiments was 0.14 ounce. Bass (1-inch) were added May 7, 1947. Ponds were drained October 17-20, 1947.

[2] In this experiment, bluegills were fed poultry laying mash during the spring and summer in addition to pond fertilization. All other ponds received only normal fertilization.

[3] Bass widely scattered around pond in stocking. Added at one place in other ponds.

in addition to competition from bluegills such as lack of young fish for food and consequent increase of cannibalism among bass may have been important. Experiment 9 in which bluegills were fed, gave the highest bass survival (92 percent). This result seemed to emphasize the important effect of sufficient food for rapid growth of both species upon bass survival.

Careful scattering of bass around the small ponds at the time of stocking did not appear better than their addition at one point. The comparative average survivals with the two methods were 74 and 86 percent respectively.

It must be emphasized that the above results merely indicate some of the problems involved in pond management and suggest the necessity for further detailed research.

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EXPERIMENTAL LARGEMOUTH BASS MANAGEMENT IN ILLINOIS

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Abstract

A fishing cycle characteristic of new water-supply reservoirs in Illinois can be predicted with a high degree of accuracy. This sequence of events poses several questions which have been answered at Ridge Lake (18 acres) during the past 9 years, largely through population manipulation during biennial draining for enumeration of the fish. A complete creel census tests the value of population adjustments. In this period of study, fishermen have taken 3,228 largemouth bass weighing 2,385 pounds and 8,169 bluegills weighing 1,168 pounds. Biologists have removed on draining censuses 6,406 small bass weighing 862 pounds and 94,582 small bluegills weighing 4,859 pounds. These fish all originated from 435 bass stocked in 1941, and 129 bluegills stocked in 1944. The hook-and-line yield of bass has varied between 10.9 and 30 pounds per acre per year.

Four censuses have indicated that the maximum carrying capacity of the lake for bass was about 50 pounds per acre. When the bluegill population was allowed to expand to 193 pounds per acre, the bass population was depressed to 31.5 pounds per acre. During years when the population of small bass and bluegills was thinned in March, the June reproduction of bass averaged 54,200 schooling fry. In alternate years, when the lake was not drained and contained many small fish of the preceding year, the average bass reproduction was only 5,900 schooling fry. In the alternate years of 1948 and 1950, no schools of young bass were found, no young bass were taken in seining with a ⅛-inch mesh minnow seine in 1948, and only one was taken in 1950. The bass population of Ridge Lake has been maintained at a high level, in spite of the fact that small bass were removed on draining censuses and that since 1945, fishermen have been asked to remove them from the lake when caught. This suggests that legal length limits have no value in bass conservation. The differential in spawning success between years when small fish were removed prior to spawning and years when they were not, casts doubt on the utility of closed seasons and bag limits. Bass have always been protected at Ridge Lake during the spawning season, yet there has been no correlation between the number of bass of spawning size in the lake and the number of young bass produced. In the author's opinion, bass populations in Illinois bear no direct relationship to populations of other fishes, except that they may be depressed by them.

Introduction

The history of fishing in new water-supply reservoirs in Illinois has followed such a uniform pattern that it has been possible to predict the following sequence of events (Bennett, 1946): (1) first year, bass, crappies, bluegills, and bullheads stocked as adults; bass spawn greatly exceeds that of all other species; (2) second, third and fourth years, reservoir very clear, bass fishing excellent, good catches of crappies, bluegills and bullheads of large average sizes; recreational attractions, fishing, swimming and boating at a maximum; (3) fifth, sixth and seventh years, bass fishing about gone except for a few large individuals, crappie and bluegill fishing still fair to good but fish caught are of small sizes, water muddy most of the time, with indications of a large rough fish population; (4) from about the seventh or eighth year on, almost no bass fishing, crappies and bluegills usually small and stunted, bullheads either few and of large average sizes or very numerous and small, fishing usually poor, water muddy at all seasons due to the rooting action of rough fish, recreational attractions at a minimum. This sequence of events is an ecological succession resulting from intra- and inter-specific competition among the offspring of fishes that have entered the reservoir as the original stocking of fish and through movement into the impoundment from the feeder streams.

For those interested in bass fishing and management, this ecological sequence poses several questions: (1) when a new reservoir is stocked with small numbers of adult fishes in which the number of bass is frequently much smaller (because they are hard to get in quantity) than those of other species, why are bass usually able to out-spawn every other species to such an extent that almost no young fish other than bass may be seined up along the shoal areas; (2) why are bass unable to produce spawn in later years in numbers comparable to that of the first year, and (3) can the circumstances that are responsible for a heavy first spawn of bass in new reservoirs be duplicated in later years in reservoirs built primarily for fishing?

Management of Ridge Lake, Illinois

Ridge Lake, in Fox Ridge State Park near Charleston, Illinois, is an artificial impoundment of 18 acres, constructed in 1941 for recreation and fisheries research in a steep-sided valley containing a small tributary of the Embarass River. The dam is supplied with a 4-foot gate valve through which the lake may be drained. Fox Ridge State Park is located in light-colored, medium-textured, upland timber soils, with moderate to slow permeability. The predominant soils which occupy 95.8 percent of the total area of the lake watershed are the Ward silt loam group. According to the agricultural agent of Coles County, the soils in the flat lands draining into Ridge Lake produce an average corn yield of not more than 25 bushels per acre as compared to an average 75 bushels per acre on the black soils of central and northern Illinois. Thus, it was to be expected that Ridge Lake would be much less productive of fish than impoundments farther north in the State.

Ridge Lake was stocked with 100 sexually mature largemouth bass in May, 1941. After the spawn appeared in early June, 335 yearling bass were added to reduce the survival of bass fry. No other bass have been stocked. In late June of 1944, 129 adult bluegills were introduced. Beginning in 1942, public fishing was allowed from boats owned by

Table 1.—*Largemouth bass and bluegills removed from Ridge Lake by drainage and by anglers during the 1941-1949 period. These fish all originated from an original stocking of 435 bass in 1941 and 129 bluegills in 1944. Results expressed as total numbers, total weight, and pounds per acre.*

Year	Species											
	LARGEMOUTH BASS						BLUEGILLS					
	Removed by fishermen			Removed by draining			Removed by fishermen			Removed by draining		
	Number	Weight, pounds	Pounds per acre	Number	Weight, pounds	Pounds per acre	Number	Weight, pounds	Pounds per acre	Number	Weight, pounds	Pounds per acre
1941	51	8.2	0.5	....	....	....	....	....	....	....	....	....
1942	485	271.7	15.1	....	....	....	....	....	....	....	....	....
1943	32	17.9	1.0[1]	2,783	482.3	26.8	....	....	....	....	....	....
1944	466	270.5	15.0	....	....	....	....	....	....	....	....	....
1945	409	356.9	19.8	494	197.0	10.9	2	1.2	....	10,000	100.0[2]	5.6
1946	362	263.4	14.6	....	....	....	1,677	226.7	12.6	....	....	....
1947	181	195.6	10.9	2,117	79.6	4.4	644	111.6	6.2	64,868	3,195.0	177.5
1948	648	460.0	25.6	....	....	....	5,831	826.0	45.9	....	....	....
1949	594	540.5	30.0	1,012	103.0	5.7	15	2.9	0.2	19,714	1,564.3	86.9[3]
Total	3,228	2,384.7		6,406	861.9		8,169	1,168.4		94,582	4,859.3	

Total bass—9,634 weighing 3,246.6 pounds.
Total bluegills—102,751 weighing 6,027.7 pounds.

[1] Taken by Survey biologists in the years the lake was not opened to public fishing.

[2] An estimate of bluegill fingerlings about 2 inches long.

[3] Bluegills removed in drainage census of March, 1949.

the Natural History Survey and furnished to the public on a reservation basis without charge. As state fishing licenses of anglers were left at the laboratory pier and fishermen were checked in and out of the boats by a biologist, it was possible to gather complete information on fishing.

In 1943 and biennially thereafter (1945, 1947, and 1949) the lake was drained, the fish were counted, and only marked bass, 9 inches or more in length and a limited number of marked bluegills 6 inches or more in length (after 1944) were returned. Small numbers of other species of fish that moved into the lake from the stream above or over the surface spillway from below in time of high water, were completely eliminated in these draining censuses.

THE CROP OF FISH, 1941-1949

The fish removed from Ridge Lake throughout the 9-year period are shown in Table 1. The annual yield of bass from angling, except in the years 1941 and 1943 when Ridge Lake was not opened to the public, has varied between 10.9 and 30 pounds per acre. In 1943 the lake was closed to public fishing because at the time of the draining census in March, a large part of the bass returned were below the legal limit of 10 inches. From 1945 to the termination of the present study, fishermen were asked to bring in all illegal as well as legal bass and the illegal fish were confiscated at the laboratory pier. These illegal fish were not counted in a limit, so that a fisherman could take 10 legal bass and any number of illegal ones. Fishermen were asked to bring in all bluegills caught and since there is no length limit on bluegills in Illinois and a bag limit of 50, small fish that the fishermen did not want were left at the pier.

The hook-and-line yield of bluegills varied during the years when large bluegills were present in numbers (1946, 1947, and 1948) between 6.2 and 45.9 pounds per acre. The 129 bluegills stocked in late June of 1944, spawned throughout the rest of the summer, and an estimated 10,000 young were removed from the lake as 2-inch fingerlings the following March (1945). Following this census, the 61 adults that remained from the original 129, were restocked. These, plus an unknown number of the 2-inch fish that managed to remain in the feeder stream within the lake basin, constituted the bluegill population in 1945. It was not until 1946 that fishermen began to catch bluegills of worthwhile sizes.

In the draining operation of March, 1947, the bluegill inventory of fishes above 2.5 inches in length was 66,629. Many fish of smaller sizes passed through the screens with the lake water and were not included. Only 1,761 of the larger bluegills were restocked, although again there was evidence that some small bluegills escaped the census by staying within the lake basin. The yield of bluegills to the angler in 1947 was 644, and in 1948 was 5,831.

Table 2.—*Total weight of fish recovered at time of lake drainage and total weight returned after each drainage—expressed as pounds per acre for the years 1943-1949 inclusive.*

Year	Recovered at time of drainage				Returned after drainage	
	Largemouth bass	Bluegills	Other fish	Total in census	Largemouth bass	Bluegills
1943.......	48.2	....	0.5[1]	48.7	21.4	....
1945.......	39.6	7.0	25.7[1]	72.3	28.7	1.4
1947.......	31.5	193.3	31.5[2]	256.3	27.0	15.8
1949.......	50.4	86.9	2.9[3]	140.2	44.7	....

[1] Black bullheads and green sunfish.
[2] Black bullheads, green sunfish, carp, and one black buffalo.
[3] Black bullheads, yellow bullheads, and green sunfish.

In the 1949 drainage census the bluegill count was only 19,714. After the water in the reservoir had been lowered until none remained except the flow in the feeder stream, this stream was poisoned with a commercial rotenone product. This attempt to kill the bluegills remaining in the stream channel was unsuccessful, since 15 were caught by anglers in 1949 and by the summer of 1950 small bluegills could be seen in schools in the upper lake and under the laboratory pier.

The poundages per acre of bass, bluegills, and other fish taken in the censuses of 1943, 1945, 1947, and 1949, and the poundages per acre of bass and bluegills returned following the censuses are shown in Table 2. A few bullheads (mostly *Ameiurus melas melas* (Raf.), but a few *A. natalis natalis* (LeSueur) and green sunfish (*Lepomis cyanellus* (Raf.)) entered from the small stream feeding the lake and multiplied in the 2-year periods between draining censuses. The carp *(Cyprinus carpio)* and buffalo *(Ictiobus niger* (Raf.)*)* taken in the 1947 census were believed to have moved in over the surface spillway from below during periods of high water.

There is no indication of uniformity in the poundage of bass or bluegills supported by the lake from one draining operation to the next. This condition is understandable in the case of the bluegills, where drastic thinning of fish of all sizes occurred at each draining. In the case of the bass, however, where all fish of 9 inches in length or larger were returned following a census, one might expect to find greater uniformity in successive censuses. Since the bass population approached 50 pounds per acre on two of the enumerations, it is possible that this poundage approaches the maximum carrying capacity of the lake for this species. From the 1947 census it seems safe to assume that the carrying capacity of the lake for bluegills is something over 190 pounds per acre. The poundages of bass returned to Ridge Lake following the 1945 and 1947 censuses (28.7 and 27.0 pounds per acre, respectively) were fairly comparable, yet the yield in 1945 was 19.8 pounds per acre and in 1947 only 10.9 pounds per acre (Table 1). The fishing pressure in 1945 was 105 man-hours per acre; in 1947 it was 155 man-hours per acre.

Beginning in 1947 and 1948, both the poundage of bass supported by the lake and the yield began to rise. The yields to the angler in 1948 and 1949 were both considerably greater than in any previous year and the census of 1949 showed over 50 pounds of bass per acre. A preliminary check of the 1950 creel indicates that the catch for this year may fall below that of the past two seasons.

Annual Bass Reproduction

From a study of the annual reproduction of bass at Ridge Lake it appears that bass must be highly vulnerable in the egg, yolk-sac fry, and free-swimming fry stages to predation from small fishes, and that under conditions of an abundance of small fishes, the reproduction for an entire year may be practically eliminated. Physical conditions in the lake at the time of spawning undoubtedly affect the degree of its success, but these factors are believed to be of lesser importance.

Estimates of the number of young bass produced in Ridge Lake each year are made by rowing around the lake shallows every day during the spawning period, counting the individual schools of bass, and estimating the numbers (in hundreds) in each school. Early in the season a few schools are usually located and these are found in about the same locations from day to day. As the spawning season advances, more and more schools appear, and a peak count made on any one day is taken as the estimated reproduction for that year. A few days later the schools break up and the fish are scattered in shallow water along shore. These counts of young bass cannot be considered accurate, but since the technique has been the same year after year, the figures are considered valid for comparison.

Circumstantial evidence that small fish largely control the survival of bass spawn is given in Table 3. The spawn recorded for 1941 was that of the original 100 bass of mature sizes stocked in April of that year. In 1942, the spawn was quite successful (26,000 fry), but an age analysis of the Ridge Lake bass population based on scale samples from fish taken in later years shows that few of the fish of the 1942 year class survived.

In the other years when the population of small fish was not culled (1944, 1946, 1948, and 1950), the survival of young bass to the schooling stage was apparently insignificant. In both 1948 and 1950 no schools of bass were observed. In 1948 several hauls with a fine-mesh, 20-foot minnow seine failed to catch any small bass, although yearling bluegills and bluegill fry were abundant. In 1950, one small bass was taken in one of 5 hauls with the minnow seine.

In contrast, during years when the population of small fish was thinned, the adult bass always produced significant numbers of young. The average number of young bass for all years in which the small

Table 3.—*Estimates of the numbers of young bass to reach the schooling stage in years when small fish were culled from the Ridge Lake population and in years when small fish were present.*

Small fish absent		Small fish present	
Year	Estimated number of young bass	Year	Estimated number of young bass
1941	76,000	1942	26,000[1]
1943	18,000	1944	1,000[1]
1945	116,000	1946	2,500
1947	37,000	1948	0[2]
1949	24,000	1950	0[2]
Total	271,000		29,500
Average	54,200		5,900

[1] Only bass were present in the lake until mid-summer of 1944.

[2] No schools of young bass could be found in 1948 or 1950. Extensive seining with a minnow seine produced no small bass in 1948. In 1950 one small bass was taken in one of five minnow seine hauls made in various parts of the lake.

fish were thinned was 54,200 as compared to an average of 5,900 for alternate years. In years when the population of small fish was culled the survival of young bass beyond the schooling stage was apparently satisfactory because the stock lost through fishing and draining operations was replenished.

Discussion

A satisfactory yield of bass has been maintained at Ridge Lake over a period of years exceeding that of the usual "fishing life" of most new water-supply reservoirs. This yield is the result of good production and survival of bass fry as often as once in 2 years. Under the system of biennial draining, bass spawned in the first year of the biennium must have attained a length of 9 inches at an age of 21 months (two growing seasons) or they are removed from the lake. It is probable that only the cannibals of the bass brood spawned in the second year of the biennium are large enough to survive the census, although a small number of small bass (and bluegills) escape the culling operation by remaining in the feeder stream within the lake basin.

In the author's opinion, the use of a drain valve for the management of fish populations in artificial lakes surpasses all other techniques in value, and no farm pond or artificial lake built for recreation should be planned without an outlet so situated and of such size that all water and fish in the impoundment will pass under the dam to the downstream side where a simple screen can be installed to trap the fish. If the draining operation is done in cold weather, the fish may be concentrated in holding tanks until sufficient water has again collected above the dam for the restocking of selected fish. In larger lakes the stilling basin at the lower end of the surface spillway may be pumped full of water and used as a holding tank.

With a pond or lake supplied with a drain outlet, the significance of correct stocking becomes less, and the problem of controlling the entrance of undesirable species of fishes is easily solved. Unquestionably, the carp that entered Ridge Lake between the 1945 and 1947 draining censuses would have produced a successful spawn within a few years. Also, the problem of overpopulation and stunting, which is the most common cause of poor fishing in Illinois (Bennett, 1943), may be prevented without resorting to the use of commercial fertilizer or to poisoning the fish and starting over again with a new stock.

For those that are primarily interested in bass management, the Ridge Lake experiment and several others, both published and unpublished, present some points of interest. First, good bass fishing stems from a large population of bass that is capable of replenishing its losses through the periodic production and survival of young.

Second, high production and survival of young bass is closely related to the absence of severe predation by small fishes on bass eggs and fry. This type of predation takes place even where the spawning adults are given complete protection from angling (as at Ridge Lake). The survival of young bass seems to vary inversely with the numerical size of the population of small fishes. Therefore, it becomes a logical assumption that measures long advocated for the protection of bass by the conservation agencies of this country, such as length limits, closed seasons, bag limits, and the barring of bass and panfish to commercial fishing, have done little or nothing to increase bass populations and thereby improve bass fishing.

The assumption made by Swingle (1950) that a population of bass in a lake bears, or should bear, any particular weight relationship to populations of one or several other species of fishes in that lake does not appear to be valid. Such an assumption must be based on a direct predator-prey relationship which does not exist (Johnson, 1949), largely because bass are rather omnivorous in their selection of food items and appear to prefer crayfish and their own young, to the young of fishes stocked as companion species. For this reason, bass cannot be expected to control for any great length of time, the expansion of populations of these companion species. Where populations of companion species are not controlled by natural forces or through artificial means, the populations of bass gradually become smaller, because recruitment from natural reproduction is inadequate, until they may eventually disappear.

When tabulations of the fish populations of 37 Illinois ponds and lakes, on which censuses have been made, were arranged in order of ascending poundages of bass per surface acre, five at the top of the list contained no bass, and the next five contained bass populations of less than 5 pounds per acre (Bennett, 1943 and unpublished data). While adequate records of the original stocking of these waters are not available, 3 of the 10 were reported to have furnished good bass fishing in years past. In every case where bass were present, these low populations were composed of a few fish of large sizes, and there was no indication of any bass reproduction.

At the bottom of the list were five ponds and lakes that were supporting bass populations of 50 or more pounds per acre. Of these, the largest poundage was found in Fork Lake (122 pounds per acre) that had been poisoned and restocked with bass and bluegills in 1938 and then, beginning in 1939, had been intensively cropped with 1-inch mesh wingnets for 3½ years previous to the census (Bennett, 1948).

The second highest poundage of bass (76.5 pounds per acre) was found in Duck Valley Lake on the Fin 'n Feather Club near Dundee, Illinois, where an annual practice of stocking of 6- to 10-inch bass was combined with an annual feeding program of several tons of minnows seined from Lake Michigan.

Other ponds that contained these higher poundages of bass were: Upper Twin Lakes (57.9 pounds per acre) which had been seined yearly for obtaining fish for a club fish fry; Onized Lake (50.8 pounds per acre) that had been subjected to an annual fishing pressure of more than 1,400 man-hours per acre for several years prior to the census (Bennett, 1945), and Elam Pond (49.9 pounds per acre) that had been stocked 5 years previous to the census with a small number of bass fingerlings.

All of these waters which contained the higher poundages of bass were either subjected to cropping practices which at present would be considered abnormal (Fork Lake, Upper Twin Lake, Onized Lake), or were subjected to an artificial system of stocking and feeding (Duck Valley Lake), or were originally stocked with bass alone.

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Nearly every biologist who has been on the staff of the Aquatic Section of the Illinois Natural History Survey between 1941 and the present has given assistance in some phase of the Ridge Lake study. On each of the four biennial draining censuses, we have requested and received able assistance from members of the Division of Fisheries, Illinois Department of Conservation.

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TISSUE LEVELS OF VARIOUS SULFONAMIDES IN TROUT

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Abstract

Studies were made on the tissue levels of sulfonamides in trout. The tissue concentrations of sulfamerazine were determined in brook trout given various doses of this drug. It has been found also that there exists a relationship between the rate of feeding, depending on the size of trout, and the tissue concentration of sulfamerazine. The level of sulfamerazine rose much faster and higher in blood and liver than in kidney and muscle. However, after the treatment was discontinued sulfamerazine level in all tissues dropped within 3 days to about 1 milligram percent. From the tested sulfonamides, sulfanilamide was absorbed fastest and produced highest tissue concentration. Sulfamerazine and sulfamethazine gave similar tissue levels, but the tissue concentration rose faster with sulfamerazine. Sulfadiazine and sulfaguanidine reached lower tissue levels. The tissue level of sulfathiazole was less than 1 milligram percent and sulfathalidine and sulfaquinoxaline were not absorbed from the intestine at all.

Introduction

Sulfonamides were first tried for the treatment of trout diseases by Tunison and McCay (1937) and Wolf (1939). These authors tried unsuccessfully to treat ulcer disease by feeding infected trout with food containing large doses of sulfanilamide, the only sulfa drug in general use at that time. When new sulfonamides were introduced, the most promising of them were tested by Gutsell (1946, 1948) who found that sulfamerazine was very effective in the treatment of trout infections caused by *Bacterium salmonicida.* Studies carried out by Wolf (1947) confirmed, in general, the results obtained by Gutsell, and indicated that sulfamerazine therapy was also promising in the treatment of ulcer disease. Gutsell and Snieszko (1949a) determined the optimum dosage of sulfamerazine for the treatment of furunculosis and described (1949b) the effect of this drug on the growth of normal trout of three species. In subsequent studies Snieszko *et al.* (1950) found that in addition to sulfonamides tested by Gutsell (1946), sulfamethazine was about as effective as sulfamerazine in the treatment of furunculosis, and that sulfathiazole was inferior. Recently Slater (1948) used sulfonamides with promising results in the treatment of a salmon disease caused by *Chondrococcus columnaris.*

The first pharmacological investigations were carried out by Litchfield (1939) on a normal spiny dogfish *(Squalus acanthias).* Flakas

(1950) determined the blood concentration of sulfonamides in adult brown trout which were therapeutically effective. The rate of penetration of the intestinal wall of trout by various sulfonamides, their distribution in blood and other tissues or organs, as well as the speed with which they were eliminated remained unknown. The objective of the present study was to secure information which would permit a more effective use of sulfonamides for the treatment of some infectious diseases of fishes.

METHODS

Fingerlings or yearlings of brook *(Salvelinus fontinalis)*, brown *(Salmo trutta)*, or rainbow trout *(Salmo gairdnerii)* were graded, weighed, and distributed into experimental troughs. The temperature of the water was 11° to 13° C. Doses of sulfonamides were expressed in milligrams per 100 grams (milligrams percent) of trout weight per day. The concentrations of sulfonamides in blood or tissues of treated fish were also expressed in milligrams percent. Sulfonamides were mixed with the diet and fish were fed at 8 A.M. and 4 P.M. each day. The quantity of food given to the experimental trout was determined from the feeding charts (Duel *et al.*, 1942) based on requirements per unit of body weight. With small fish it was desirable to determine sulfonamides in entire trout rather than in blood only. In order to eliminate the non-absorbed drugs, the intestinal tract and feces were carefully removed and trout were ground with known volume of distilled water in a Waring blender. For a comparison sulfonamides were determined in a similar way in blood and some of the organs. Usually determinations were made from composite samples of three to five trout. All determinations were made colorimetrically with the method of Bratton and Marshall (1939). Occasionally the total sulfonamides were determined in addition to the free sulfonamides.

RESULTS

First was determined the relationship between the doses and tissue level of sulfonamides. This experiment was carried out three times with brook trout fingerlings of various age groups. In the particular experiment here described, the doses of sulfonamide were 10, 20, and 30 milligrams per 100 grams of fish per day. The trout weighed about 23 grams per fish. Determinations were made in duplicate each day for a 14-day period from fish carried at each level of treatment. Composite samples of three trout were taken at random from separate troughs. In Table 1 and Figure 1 are presented the tissue levels of sulfamerazine from duplicate determinations. The tissue concentrations of sulfamerazine increased during the first 4 days. They were reasonably unform during the next 6 days of treatment and dropped rapidly when sulfamerazine was eliminated from food on the tenth day. The tissue concentrations decreased slightly when one feeding was missed

TABLE 1.—*Levels of free and total sulfamerazine in tissues of normal fingerling brook trout (average weight per trout 23 grams) treated at three different dosages of the drug. Determinations were made on duplicate (A, B) composite samples each consisting of three trout.*

Days after the start of treatment	Dosage rate in milligrams percent											
	10				20				30			
	Sulfamerazine in trout tissues in milligrams percent											
	Free		Total		Free		Total		Free		Total	
	A	B	A	B	A	B	A	B	A	B	A	B
1	2.0	0.1			2.8	2.6			3.8	4.2		
2	2.3	1.5	2.5	1.8	2.3	4.7	3.5	5.3	3.6	5.7	4.0	5.9
3	2.4	2.1	2.9	2.3	1.1	4.5	1.4	6.1	4.5	5.7	5.1	6.1
4[1]	3.2	3.4	4.0	3.8	5.7	7.0	6.1	8.2	8.2	6.1	8.6	6.8
5	2.1	2.4	3.6	2.9	3.1	4.2	4.0	4.9	6.1	3.2	7.0	4.7
6	3.2	3.8			6.9	6.5			9.8	7.9		
7	1.8	4.2	3.3	5.1	6.8	6.9	6.8	7.4	9.2	8.4	9.4	8.6
8[2]	3.6	3.4			6.3	6.3			6.1	7.3		
9	3.2	2.3	3.3	2.6	6.8	6.3	6.8	6.5	7.7	7.7	7.9	7.9
10[3]	1.6	2.0			3.8	4.7			4.7	4.7		
11	0.5	0.9	0.8	0.9	1.6	2.4	1.6	2.6	2.0	1.7	2.0	1.8
12	0.1	0.4			0.8	0.5			0.6	0.6		
13	0.1	0.1	0.2	0.8	0.1	0.4	0.2	0.5	0.2	0.1	0.4	0.4
14	0.4	0.1			0.2	0.2			0.2	0.2		

[1] On the fourth day one afternoon feeding was missed.

[2] After 7 days diets were adjusted to trout weight.

[3] After 9 days treatment with sulfamerazine was discontinued.

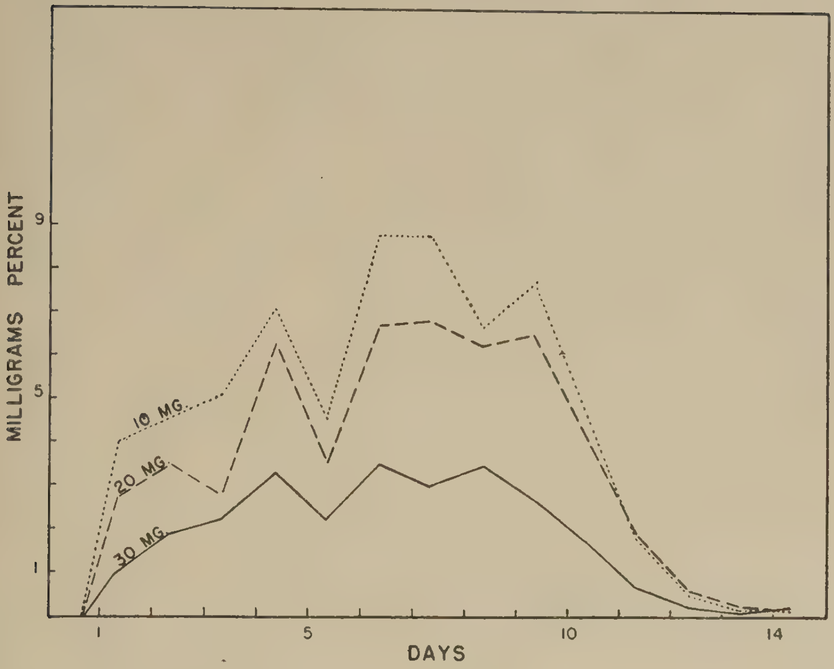

FIGURE 1.—Average levels of free sulfamerazine in tissues of normal brook trout fingerlings treated with three different dosages of the drug. Afternoon feeding missed on the fourth day; diets adjusted after 7 days; and treatment discontinued after 9 days. Dosages are in terms of milligrams per 100 grams of trout per day.

on the fifth day, and also when the dosage was adjusted to the weight of the fish on the eighth day. The experiment indicated that the increase of the dosage rate resulted in increase of the tissue concentrations of sulfamerazine.

Results of this, and of two other experiments, are also presented in Figure 2. They show that the tissue concentrations of sulfamerazine given at the same doses were higher in older fish which were fed at a lower rate (Duel *et al.,* 1942). This relative increase of the level of sulfamerazine in older trout is due to the reduced quantity of food.[1]

For rational treatment of the infectious diseases of fishes with sulfonamides, it was important to establish the therapeutically effective concentration of the drug in the blood, and to maintain it at this level during the whole period of treatment. To test the value of the high initial dose in fishes, brook trout fingerlings, average weight 33 grams, were divided in three lots and six troughs. All trout were treated at

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[1] Results of this and other additional experiments will be published later.

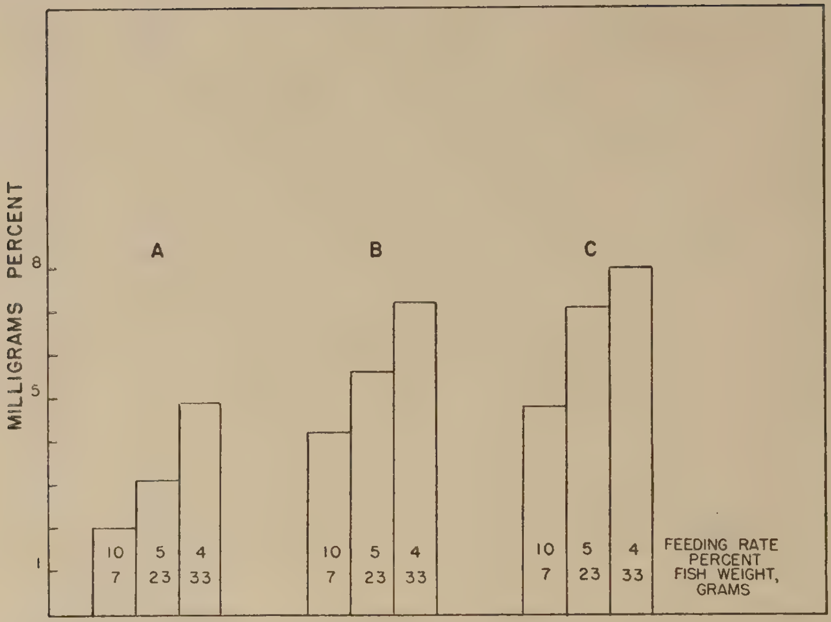

FIGURE 2.—The average tissue levels of free sulfamerazine in three lots of brook trout fingerlings. Each lot was of different age and size, and was tested at different times. Each lot was fed at a different rate (Duel *et al.* 1942). Dosages are, A 10, B 20, and C 30 milligrams per 100 grams of fish per day.

first with sulfamerazine at the relatively high rate of 30 milligrams per 100 grams of fish per day. The tissue concentration rose slowly until it started to level off on the fourth day at 9 milligrams percent. From the seventh day, fish in each pair of troughs received sulfamerazine at different rates of 10, 20, and 30 milligrams percent. In trout receiving 10 and 20 milligrams daily doses, the tissue levels dropped considerably within several days. In these trout it was only slightly higher than in trout used in other experiments in which fishes were treated with identical dosages but without the benefit of the high initial doses. This slight increase was due to the larger size of fish used in this test which received food at a lower rate (Duel *et al.,* 1942). The advantage of high initial dosage in trout was the somewhat shortened time with which the higher tissue level was reached. The subsequent lower doses did not permit the maintenance of the high tissue concentration obtained by the high initial dosage.

The concentrations of sulfonamides in man and larger domestic animals are determined from blood samples. In small trout this is not practical because the quantity of blood which can be obtained is usually inadequate for such purposes. Therefore in order to be able to com-

TABLE 2.—*Levels of free sulfamerazine expressed as milligrams percent in various tissues and feces of yearling brook trout (average weight 83 grams) which received the drug at the rate of 20 milligrams per 100 grams of fish per day. Determinations were made with composite samples, each of six trout.*

Days after the start of treatment	Tissue or organ				
	Muscle	Blood	Liver	Kidney	Feces
2	3.4	7.4	7.0	5.1	....
3	4.2	7.2	10.0	10.0	300
8	7.9	14.2	15.6	11.4	750
9	8.6	25.0	22.0	12.4	500
10	7.2	13.0	13.6	11.1	245
11[1]	5.7	10.6	11.4	7.9	....
14	5.5	8.0	8.0	7.2	340
15[2]	5.3	9.0	9.0	7.2	115
16	2.0	2.6	3.6	2.1	40
17	0.6	0.9	1.6	0.9	12
18	0.5	0.8	1.2	0.5	5.5

[1] Quantity of drug and diet was adjusted to the weight of trout.
[2] Treatment with sulfamerazine was ended.

pare the relative concentrations of sulfonamides in the blood and some organs of trout with that of the entire fishes, determinations were made with blood, kidney, liver, and muscle tissues of yearling brook trout. All tests were run with composite samples consisting of blood and tissues pooled from six trout for each determination. As it is evident from Table 2 and Figure 3, the concentration of sulfamerazine reached highest levels in blood and liver. In the kidney tissue it was somewhat higher than in the muscles. It is interesting to note that the concentration of sulfamerazine increased rapidly up to the ninth day and then dropped sharply although the dosage was continued at the same rate. The concentration of sulfamerazine in the contents of the gut during the treatment was very high (Table 2). Feeding a diet containing sulfamerazine was discontinued on the 14th day. Consequently, the concentration of sulfamerazine decreased uniformly in blood and other tissues. When on the 17th day the concentration of the drug in all tissues was only 1 to 2 milligrams percent, in the intestinal contents it was still about 12 milligrams percent. This experiment was repeated at another time with brown trout yearlings and the results duplicated the data here presented.

Finally, the tissue concentrations of eight different sulfonamides which have been tried in the treatment of furunculosis or other fish infections were determined. All sulfonamides were given to brook trout fingerlings weighing on the average 2.5 or 4.0 grams per trout. All determinations were made with composite samples of five trout. Results are presented in Table 3 and Figure 4. Sulfanilamide was absorbed very rapidly and reached the tissue concentration of 8 to 9 milligrams percent. The concentration started to drop from the ninth day regardless of continued treatment. This sudden drop of tissue concentration

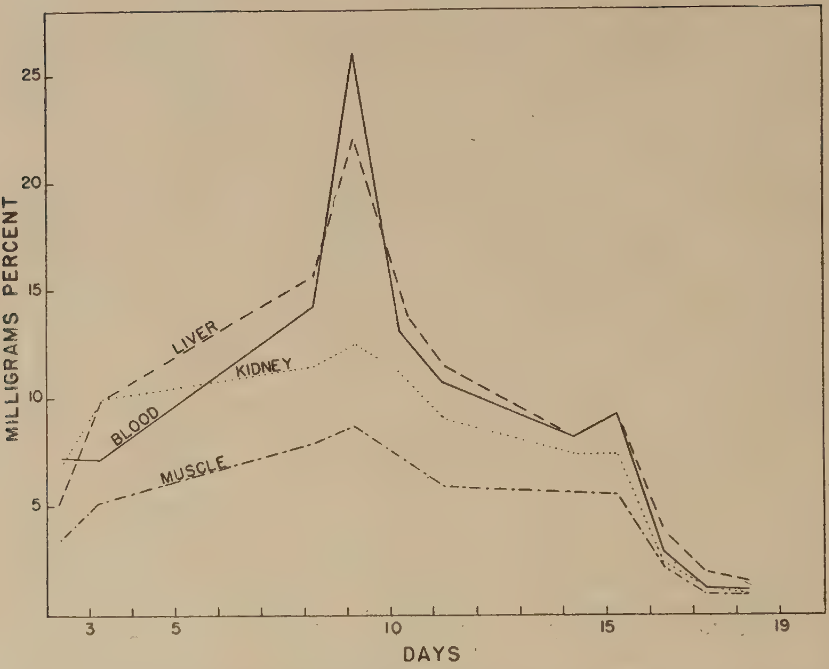

Figure 3.—Levels of free sulfamerazine in various tissues of brook trout yearlings which received the drug at the rate of 20 milligrams per 100 grams of fish per day. (M) muscle; (B) blood; (L) liver; (K) kidney. Concentration in feces too high to be shown.

of sulfanilamide was due to some undetermined cause. The tissue concentration of sulfamerazine reached a somewhat lower level than that of sulfamethazine but the absorption of the former was faster. This observation accounts for the results of Snieszko *et al.* (1950), who found that the therapeutic action of sulfamethazine was somewhat slower than that of sulfamerazine. It is interesting to note that sulfathiazole was only slightly absorbed. Nevertheless, this drug was moderately effective in the treatment of furunculosis (Gutsell, 1948; Snieszko *et al.*, 1950). Sulfathalidine and sulfaquinoxaline were not absorbed from the intestinal tract. The latter was tried in the treatment of furunculosis and was found ineffective.

Discussion and Recommendation for Treatment

The development of chemotherapy for any infectious disease is not a purely empirical process based on testing innumerable drugs. The pharmacological basis for chemotherapy depends on the understanding of the action, distribution, and excretion of drugs in the body. There is

TABLE 3.—*Tissue levels of various sulfonamides in fingerling brook trout of average weight of 2.5 and 4.0 grams. Dosage 20 milligrams of sulfonamide per 100 grams of trout per day. Determinations were made on duplicate (A, B) composite samples of five trout each.*

Days after the start of treatment	Sulfamerazine[1]		Sulfaguanidine[1]		Sulfadiazine[1]		Sulfamethazine[1]		Sulfanilamide[2]		Sulfathiazole[2]	
	A	B	A	B	A	B	A	B	A	B	A	B
1	4.2	4.2	1.6	1.1	3.7	3.7	2.9	1.9	2.1	4.0	0.0	0.0
2	5.3	1.6	0.8	1.3	3.3	3.3	2.9	3.2	9.0	7.8	0.6	0.7
3	4.2	5.5	0.6	0.5	2.1	1.6	3.2	3.7	8.0	8.2	0.8	0.8
4	5.3	7.0	1.2	1.1	2.5	2.4	3.5	2.7	3.6	2.4	0.3	0.2
7	5.9	5.5	0.8	0.8	2.2	2.4	5.4	4.0	7.8	9.0	0.1	0.1
9	5.5	5.3	3.1	3.0	3.0	2.8	8.0	6.0	9.6	9.0	0.4	0.5
11	5.9	6.8	2.0	1.9	3.7	3.0	7.3	8.3	3.6	5.2	0.8	0.2
13	5.5	5.5	2.1	2.1	3.0	3.6	6.4	7.7	....	....	....	....
14	5.7	6.1	2.1	1.9	3.0	2.7	5.7	5.5	....	....	....	....
15	3.8	3.1	1.3	1.3	3.3	2.2	3.8	3.2	4.7	3.3	0.2	0.1
16	1.1	0.8	0.2	0.1	0.6	0.5	0.3	0.0	2.7	3.7	0.2	0.0
17	....	....	....	....	....	....	....	....	1.0	1.4	0.0	0.0
18	....	....	....	....	....	....	....	....	0.4	0.2	0.0	0.0

Sulfathalidine and sulfaquinoxaline were not absorbed from the intestinal tract.

[1] Treatment discontinued after 14 days.

[2] Treatment discontinued after 15 days.

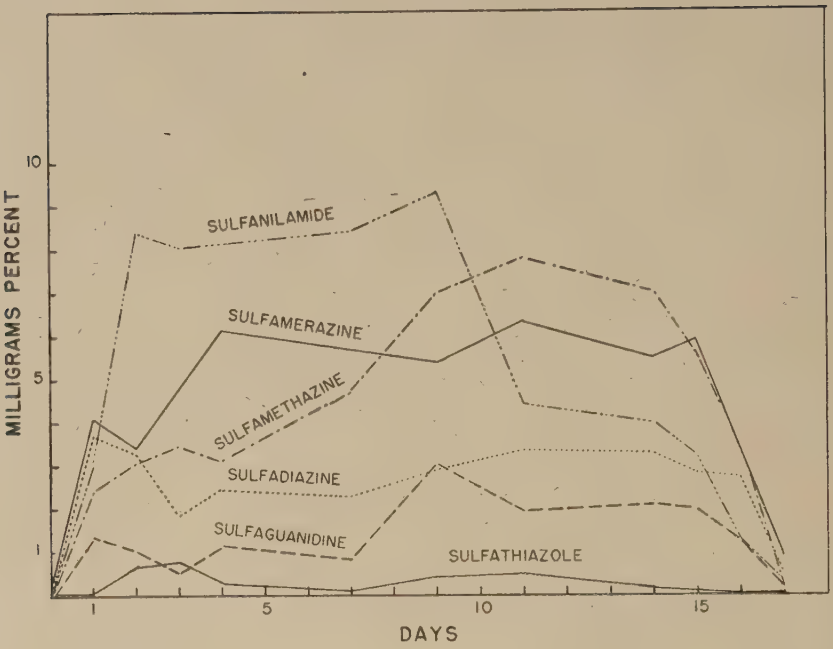

FIGURE 4.—Average tissue levels of various sulfonamides given at a rate of 20 milligrams per 100 grams of fingerling brook trout per day. There was no absorption with sulfathalidine and sulfaquinoxaline.

no certainty that a drug which is toxic to the pathogen *in vitro* will be similarly active *in vivo*. The bactericidal action *in vivo* is dependent not only on the toxicity of a drug for the pathogen, but also on the rate of absorption and excretion of drug and its power of penetrating tissues (Work and Work, 1948; Northey, 1948).

The first pharmacological study on sulfonamides in fishes was carried out by Litchfield (1939). He introduced sulfanilamide to dogfish enterally and parenterally and found that the toxic effect of the drug became evident when the blood concentration reached 5 milligrams percent. The enteral absorption *per cloaca* was very rapid, but *per os* was slower, probably as a result of the gradual and variable emptying of the stomach. This observation is in accord with those here reported, which show that the highest tissue concentration in trout was reached only after several days of treatment.

The optimum therapeutic dosage of sulfamerazine for treatment of furunculosis in brook trout according to Gutsell and Snieszko (1949) was 8 grams of the drug per 100 pounds, which is equal to 17.6 milligrams per 100 grams of fish per day. Satisfactory therapeutic results were also obtained by Gutsell and Snieszko (1949a) with lower dosages of 8.8 and 13.4 milligrams per 100 grams of trout per day. Flakas (1950) found that the therapeutically effective dosage of sulfamerazine in the treatment of furunculosis in adult brown trout was also 8 grams per 100 pounds of fish per day. After 4 days of such treatment, the blood level rose to 7 milligrams percent. The doses recommended both by Gutsell and Snieszko and by Flakas are fairly close (17.6 milligrams) to the dosage of 20 milligrams per 100 grams of fish per day. Therefore, the tissue levels produced by such dosage can be estimated with the help of Figure 2.

On the basis of the information presented in the papers here discussed, and experiments described in this report, it is possible to outline somewhat modified recommendations for sulfonamide treatment of furunculosis, and possibly, other infectious diseases of fishes.

1. Treatment should be started as early as possible, because fishes in the advanced stage of the disease cannot be saved.

2. Bacteriological examination of the diseased fishes should be carried out as soon as possible. Other diseases, which in their symptoms may be similar to furunculosis, may be refractory to the sulfonamide treatment. In case of mixed infections in which *Bacterium salmonicida* is also present, treatment with sulfonamides should be given.

3. Treatment should be started before the results of bacteriological examination are known. If bacteriological examination reveals infection with pathogens which are known to be refractory to sulfonamides, treatment should be discontinued and other measures tried.

4. Results presented in this paper show that the absorption of those sulfonamides which are most effective in treatment of furunculosis is somewhat slower in fishes than in warm-blooded animals (Litchfield, 1939; Northey, 1948). In order to bring about a fast therapeutically effective blood concentration of sulfamerazine, trout should receive during the first 3 to 4 days of treatment 20 to 30 grams of the drug per 100 kilograms of fish per day (10 to 15 grams per 100 pounds). According to Flakas (1950), about one-third of sulfamerazine should be replaced by sulfaguanidine. After this initial period, dosage can be reduced by 25 to 50 percent without lowering the blood concentration of sulfonamides below the minimum effective level.

5. The effectiveness of treatment can be increased by removal as often as practicable of all dead, sick, and runt fishes which are less likely to take adequate quantities of the medicated food.

6. Treatment should be repeated if the disease reappears. Very prolonged treatment, or treatment with inadequate dosage of drug may result in the appearance of drug-fast strains of microorganisms (Work and Work, 1948).

7. Results presented in this paper show that there was a considerable variation in the tissue concentration of sulfonamides between replicate

samples. Therefore, in order to give all fish the opportunity to get an adequate amount of the drug, it is important that it should be evenly distributed in the food. Trout should be fed expertly using no more or less food than will be taken readily.

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GROWTH RATE OF TROUT IN RELATION TO ELEVATION AND TEMPERATURE[1]

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ABSTRACT

A study of 758 trout from the West Gallatin River indicated that growth was greater at lower elevations where the water was warmer. Rainbow trout from the upper and lower sections of the West Gallatin River showed the following differences in length at the end of each year: 0.3 inch the first year, 1.3 inch the second year, 2.1 inches the third year, 2.5 inches the fourth year, and 4.0 inches the fifth year. The growth rate of cutthroat and hybrid trout showed a similar trend. The average summer difference in water temperature (early morning), between the upper and lower stations of the West Gallatin River, was 9.6° F. Condition factors did not show significant variations between sections.

A total of 184 trout from Bridger-Spring Creek did not show significant differences in growth rate. However, water temperatures in the stream did not vary greatly.

INTRODUCTION

A marked difference in the average size of trout from the upper canyon and the lower valley portions of certain mountain streams has been observed by fisheries workers, but little information has been published on this subject. The difference in the size of fish observed could result from a variable rate of growth or from the movement of the larger fishes downstream. If the difference is caused by variable growth rates, it is probably correlated with differences in water temperature. Several workers have shown that temperature influences growth rate. Hazzard (1932) found growth rate of eastern brook trout (*Salvelinus fontinalis*) to be slower in cold headwater streams than in lowland streams where temperatures were higher and growing season longer. McHugh (1941) correlated the growth rate of whitefish (*Prosopium williamsoni*) with temperature and altitude. The present study was designed to determine differences in growth rate of trout throughout a river system in relation to existing temperatures. The West Gallatin River and Bridger Creek with its tributary, Spring Creek, were selected because they were accessible and had considerable range in elevation. All are in the headwater drainage of the Missouri River system.

All species of trout known to be present in the West Gallatin River were considered in this study. The species taken, in descending order of abundance, are: rainbow trout (*Salmo gairdnerii*), rainbow-cutthroat hybrids, cutthroat trout (*Salmo clarkii*), brown trout (*Salmo trutta*), and eastern brook trout (*Salvelinus fontinalis*). Since the rainbow-cutthroat hybrids could not always be recognized, some may have been included as rainbow or cutthroat. Eastern brook trout and brown trout were taken only in the lower 30 miles, although some are reported by fishermen to be present in other parts of the river.

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[1] Contribution from Montana State College, Agricultural Experiment Station, Project No. *844*, Paper No. *230* Journal Series.

NATURE OF STREAM SYSTEMS

West Gallatin River.—The West Gallatin River rises in the northwest corner of Yellowstone National Park, in the Madison and Gallatin ranges of the Rocky Mountains, and flows for approximately 90 miles to the confluence with the East Gallatin River. It runs northwest, traversing the central part of Gallatin County, Montana. The upper 25-mile portion, nearly all within the park, is a meandering mountain meadow stream containing relatively few pools and little bank cover. A short distance north of the park the river begins its descent through Gallatin Canyon. For a distance of about 35 miles it has a straighter course and is characterized by rapids and swift water, with some pools and shelter. The gradient of this section is about 43 feet per mile. From the mouth of Gallatin Canyon to its confluence with the East Gallatin River it has less gradient (approximately 34 feet per mile). Pools are more abundant in this section, but riffle areas predominate. The stream divides into two or more channels in many places, even at low water levels.

The stream varies in width from 40 to 150 feet and has 26 tributaries (West and Stubblefield, 1948). The most important of these are Fan Creek, near the headwaters, Specimen Creek, Sage Creek, Taylor's Fork, West Fork, Squaw Creek, and Spanish Creek. In the summer much of the water in the river below Spanish Creek is diverted for irrigation purposes but there are no large dams or other major obstructions. The West Gallatin joins the East Gallatin to form the Gallatin River, which is one of three tributaries that form the Missouri River, at Trident, Montana.

For purposes of this study, the river was divided into three sections, roughly corresponding to changes of 1,000 feet in elevation. Section I extends from the mouth of the East Gallatin (elevation 4,155) to the confluence of Spanish Creek (elevation 5,190), a distance of approximately 30 miles. Section II lies between the mouth of Spanish Creek and the confluence of West Fork (elevation 6,000), about 21 miles. Section III includes that portion of the stream between the mouth of West Fork and a point 3 miles above the mouth of Fan Creek (elevation 7,100), a distance of approximately 30 miles.

Bridger Creek and Spring Creek.—Bridger Creek and Spring Creek rise in the Bridger Range and flow southwest into the East Gallatin River. Spring Creek is a small, rather swift, meandering stream, with heavy brush cover. It has an average width of about 6 feet and a length of 7 miles. Bridger Creek is a meandering meadow stream with an abundance of pools and cover. Widths vary from 10 to 30 feet. It has a total length of 18 miles, 9 miles above the mouth of the Spring Creek tributary and 9 miles below. There are 16 other tributaries to this stream.

Spring Creek and Bridger Creek below the confluence of the two streams were considered as a single stream unit. This unit was divided into five sections corresponding to 500-foot changes in elevation as follows: Section I, Bridger Creek below the 5,000 foot contour; Section II, Bridger and Spring Creeks between the 5,000 and 5,500 foot contours; Section III, Spring Creek between the 5,500 and 6,000 foot contours; Section IV, Spring Creek between the 6,000 and 6,500 foot contours; Section V, Spring Creek above the 6,500 foot contour.

METHOD OF ANALYSIS

Scale samples were secured largely from fish taken by anglers and checked by the U. S. Fish and Wildlife Service which conducted a creel census on the lower part of the river during the summer of 1949. Approximately 100 scale samples were taken by a fisheries survey party of the Montana State Fish and Game Department in August of 1948. These scales were supplemented by other samples taken by angling and electrical shocking. Scales were taken from the left side of the fish between the dorsal fin and the lateral line. Total lengths were measured in tenths of inches and weights in tenths of pounds. Scale measurements were made from the focus along the median-anterior radius to the anterior edge.

Coefficients of condition (C) were calculated for each fish using the following formula:

$$C = \frac{W \times 10^5}{L^3}$$

where W equals weight in pounds and L equals total length in inches.

Each week, during the summer of 1949, a series of water-temperature determinations was made at representative locations within each section of the West Gallatin River. All minimum readings were taken between 6:30 and 9:00 A.M. The greatest time lapse between first and last readings was 2 hours. Maximum temperatures were determined from afternoon readings taken in July and August between 2 and 5 P.M. Water temperatures were also determined at designated stations on Bridger and Spring Creeks at 2-week intervals during the summer of 1948. Temperatures were measured with a Taylor pocket thermometer calibrated at 2° F. intervals and checked against a certified chemical thermometer. All temperature determinations were made in the shade and those in the water were taken in the current.

Chemical analysis of the water followed the methods presented in *Standard Methods for the Examination of Water and Sewage* (American Public Health Association, 1946). Tests were made for dissolved oxygen, phenolphthalein alkalinity, and methyl orange alkalinity. The pH was determined with a Hellige pocket comparator.

TABLE 1.—*Average calculated total length at each annulus of rainbow trout from three sections of the West Gallatin River.*

Stream Section	Annulus									
	1		2		3		4		5	
	Length inches	Number	Length inches	Number	Length inches	Number	Length inches	Number	Length inches	Number
I..........	3.4	142	7.4	126	11.5	81	14.5	34	17.2	6
II.........	3.2	76	6.5	70	8.9	30	12.1	4	15.6	2
III........	3.1	133	6.1	83	9.4	29	12.0	6	13.2	2

WEST GALLATIN RIVER

Comparison of Growth Rates.—The growth of trout from any section of the West Gallatin River should reflect the environmental conditions of that particular section since observations of a general nature indicated no mass movement, even during the spawning season. This conclusion is supported by the work of others. Watts *et al.* (1942) demonstrated that there was no extensive movement of brook trout in Kettle Creek. Hazzard and Shetter (1938) reported that most planted rainbow and brook trout were caught within 1 to 3 miles of the point of release. The present study compares the growth rates of trout from the three main sections of the West Gallatin River previously described.

Growth rate of 351 rainbow trout was most rapid in Section I and decreased progressively in each upstream section (Table 1). A differential of 0.3 inch was found at annulus I, 1.3 inches at annulus II, 2.1 inches at annulus III, 2.5 inches at annulus IV, and 4.0 inches at annulus V, between the upper and lower sections. The differential also increased with the age of the fish. By the application of the *t* test (Pearson and Bennett, 1942), it was found that in each year of life the variation between Section I and Section III was statistically significant. At annulus I there was a variation significant to the 5 percent level between Sections I and III. The variations at this annulus between Sections I and II and between Sections II and III were not significant. At annulus II there

TABLE 2.—*Average calculated total length at annulus of rainbow-cutthroat hybrid trout from three sections of the West Gallatin River.*

Stream Section	Annulus									
	1		2		3		4		5	
	Length inches	Number	Length inches	Number	Length inches	Number	Length inches	Number	Length inches	Number
I..........	3.5	71	7.4	69	11.5	50	15.1	16	16.7	6
II.........	3.9	29	7.3	25	10.6	15	14.5	6	....	....
III........	3.5	21	6.9	18	11.0	6	....	....	....	....

TABLE 3.—*Average calculated total length at each annulus of cutthroat trout from three sections of the West Gallatin River.*

Stream Section	Annulus							
	1		2		3		4	
	Length inches	Number	Length inches	Number	Length inches	Number	Length inches	Number
I	4.1	15	7.3	14	12.2	2	....	....
II	4.7	7	7.3	5	10.8	1	....	....
III	4.1	91	6.9	66	10.1	11	10.8	1

was a variation in all cases significant at the 1 percent level. Variations at annulus III between Sections I and III were significant to the 1 percent level, but the growth rate in Section III for this group exceeded that in Section II. This variation was not significant, however. Annulus IV showed a variation significant to the 1 percent level between Sections I and II and between Sections I and III. The variation between Sections II and III at this annulus was not significant. Differences at annulus V were not tested because numbers of fish were small.

In the 121 hybrid rainbow-cutthroat trout (Table 2), the trend of slower growth in the upper sections was also characteristic, but was not as marked as in the rainbow. This fact may be due to the small number of samples taken in Sections II and III.

The 113 cutthroat trout examined (Table 3) likewise show slower growth rate in the upstream sections. However, these differences may not be significant since the samples taken in Sections I and II were small.

Brown trout and brook trout were taken only in Section I, and consequently no comparisons between sections were possible for these two species. Their average calculated lengths at each annulus are presented in Table 4, together with growth rates of the other species of trout taken

TABLE 4.—*Average calculated total length at each annulus of trout from Section I of the West Gallatin River.*

Stream Section	Annulus									
	1		2		3		4		5	
	Length inches	Number	Length inches	Number	Length inches	Number	Length inches	Number	Length inches	Number
Kind of Trout										
Brown	3.7	102	8.8	97	13.2	71	15.9	28	19.2	1
Brook	4.7	71	8.5	63	11.8	13	....	....	....	....
Cutthroat	4.1	15	7.3	14	12.2	2	....	....	....	....
Rainbow	3.4	142	7.4	126	11.5	81	14.5	34	17.2	6
Rainbow x cutthroat	3.5	71	7.4	69	11.5	50	15.1	16	16.7	6

TABLE 5.—*Coefficients of condition (C) for trout from the West Gallatin River.*

Species	Section	Age group									
		I		II		III		IV		V	
		C	No.	C	No.	C	No.	C	No.	C	No.
Rainbow	I	33.0	16	36.1	44	37.2	45	36.2	28	35.2	6
	II	29.0	5	37.7	40	35.5	27	34.6	3	......	......
	III	41.0	49	39.1	54	37.2	23	34.7	4	38.1	2
Rainbow x cutthroat	I	29.6	2	36.3	19	35.3	34	36.5	10	34.1	5
	II	35.2	4	34.5	10	38.0	9	34.8	3	41.7	2
	III	37.8	3	35.2	10	35.5	5	40.5	1	......	......
Cutthroat	I	26.4	1	33.5	12	31.6	2	......	......	......	......
	II	37.3	2	37.8	3	34.7	1	......	......	......	......
	III	36.7	25	35.8	55	37.3	10	......	......	......	......
Brown	I	40.1	5	36.8	26	35.9	43	34.0	27	37.0	1
Brook	I	45.7	8	39.3	50	36.8	13	......	......	......	......

from Section I, to illustrate the variations in growth rate between all the species of one section. These averages show a higher rate of growth for the brown and brook trout than for the cutthroat, rainbow, and rainbow-cutthroat hybrid trout. The brown trout, after the first year, exceed all other species in yearly increment.

Condition Factors.—The effects of the environment may be reflected not only in the length, but in the condition of a trout. Coefficients of condition were calculated for each age group in each section (Table 5). There was no correlation between the condition of trout and the section from which they were taken. Average condition factors were no less in the upper sections than in the lower.

Water Temperatures.—Water temperature recordings were made weekly in all sections to determine whether significant variations did exist between them. The monthly averages of morning water temperatures for each section (Table 6) show a definite lower minimum temperature at each higher elevation. Morning temperatures show a difference of 9.6° F., while afternoon temperatures exhibit only 5° F. differ-

TABLE 6.—*Average morning water temperatures by months (1949) in various sections of the West Gallatin River, expressed as degrees Fahrenheit.*

Month	Section I	Section II	Section III
May 29	....	45.0	39.0
June	48.0	44.5	40.0
July	55.0	52.5	45.0
August	55.0	52.0	45.0
September	50.0	47.5	40.0
October 2	50.0	49.0	40.0
November 12	36.5	35.0	33.0

TABLE 7.—*Afternoon water temperatures (2-5 P.M.) in various sections of the West Gallatin River—expressed as degrees Fahrenheit.*

DATE 1949	Section I	Section II	Section III
July 11	62.0	60.0	58.0
August 14	62.0	59.0	57.0

ence between the upper and lower stations (Table 7). The optimum water temperatures for trout of 55°-60° F. (Davis, 1946) are reached in all parts of the river during the afternoons of the warmer months. However, the length of time these temperatures exist during the day, and during the year, is much less at high elevations. Daily and seasonal temperature fluctuations are also more extreme at the higher elevations.

Chemical Analysis.—Limited chemical analysis of the water was made in each section to determine differences which might influence growth. No appreciable differences existed between the various sections. In all cases, dissolved oxygen was near the saturation point, and completely adequate. Methyl orange alkalinity tests indicate moderately hard water at all stations, and hydrogen-ion concentration was in the alkaline range.

BRIDGER CREEK AND SPRING CREEK

Comparison of Growth Rates.—An attempt was made to correlate the growth rate of 98 rainbow and 86 eastern brook trout from five sections of Bridger and Spring Creeks with their distribution and the water temperature. The sample size was considerably smaller than in the West Gallatin River and the part of the stream system studied was not as long as any one section of the West Gallatin. No consistent differences in annual length increments could be shown, even between more distant sections (Table 8).

TABLE 8.—*Average calculated total length at each annulus of rainbow and eastern brook trout from the Bridger-Spring Creek system.*

Specie	Section	Annulus							
		1		2		3		4	
		Length inches	Number	Length inches	Number	Length inches	Number	Length inches	Number
Rainbow	I	3.3	25	6.3	23	8.7	12	11.4	2
	II	3.9	54	6.7	42	8.4	10	10.9	1
	III	4.1	15	6.7	10	....	....	....	....
	IV	4.3	4	6.5	2	....	....	....	....
Brook	I	4.9	3	7.7	1	....	....	....	....
	II	4.4	23	6.7	11	11.0	2	....	....
	III	3.8	17	6.5	15	....	....	....	....
	IV	3.9	26	6.4	14	....	....	....	....
	V	4.2	17	6.9	12	10.7	1	....	....

Condition Factors.—Condition factors for rainbow and eastern brook trout showed no correlation between their condition and the section from which they were taken. As in the West Gallatin, C values and length were not correlated.

Water Temperature. — Temperature readings were also made in Bridger Creek to determine variations of water temperature. No great differences in water temperatures were observed between the upper and lower sections. The greatest difference observed was 7° F., and the least difference was 2° F. However, temperatures were not taken at times comparable or frequent enough to give conclusive evidence on this point.

Chemical Analysis.—Limited chemical analysis of the water of the Bridger-Spring Creek system was made to determine whether any chemical conditions were present which might affect growth differently in one section than another. The data showed no great variation between sections. Dissolved oxygen was adequate in all cases. Methyl orange alkalinity tests showed the waters to be moderately hard at all stations, and hydrogen-ion concentration was in the alkaline range.

CONCLUSIONS

Comparisons of the growth rates, elevations, and water temperatures in sections of the West Gallatin River indicated that at each higher elevation there were smaller annual length increments and lower water temperatures. The variations in growth rate have been shown to be significant for rainbow trout. Definite trends have also been established for rainbow-cutthroat hybrid trout and cutthroat trout. Trout from Bridger Creek showed no consistent differences in annual length increments and no great temperature variations were found in the stream.

Belding (1928) says, "growth is governed by . . . the rate of metabolism of the fish," and further, "cessation of growth apparently depends upon the reduction of metabolism by the temperature." Needham (1938) cited extreme fluctuation of water temperature as a cause of lowered growth rate. In the West Gallatin there was a marked seasonal variation in temperature and in the upper sections the daily fluctuation was quite pronounced, probably due to the lack of shade. The variations found between the upper and lower sections may be sufficient to account for the differences in yearly length increments, although other environmental factors not evaluated may also have affected the rate of growth. Bridger Creek temperature and growth data are too limited to be more than suggestive of the part played by temperature. If temperature is the determining factor, then it does not have the same effect on condition (C) as it does on length. No significant difference in C was shown between the various sections of either stream system.

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THE EFFECT OF FIN REMOVAL ON FINGERLING LAKE TROUT (*CRISTIVOMER NAMAYCUSH*)[1]

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Abstract

Four lots of fish marked by fin removal were held at the State fish hatchery, Marquette, Michigan, to ascertain the amount of fin regeneration, comparative survival, and comparative growth which would follow this treatment over varying periods of time. It was determined that the following percentages of the surviving marked fish should be recognizable (regeneration 0-50 percent of the fin area) in the future: 1944 mark, dorsal and adipose fins clipped, 90.4 percent; 1945 mark, right pectoral fin clipped, 96.5 percent; 1946 mark, left pectoral fin clipped, 89.8 percent; 1947 mark, right pelvic fin clipped, 64.1 percent. Observations of fin regeneration suggested further that the calculated numbers of marked fish surviving in the mortality-growth experiments conducted at the same time should be adjusted upward, as it was demonstrated that from 0.2 to 20.8 percent of the survivors of the regeneration experiments had fully regenerated fins when examined at various times during the course of the experiments. The difference in mortality which occurred among marked and normal lake trout fingerlings in experiments performed under identical conditions and initiated with equal numbers of fish was concluded to be of insignificant proportions for the 1944, 1945, and 1947 markings. However, on the basis of chi-square tests for the departure of normal:marked fish from the originally established ratio, removal of the left pectoral fin appears to have resulted in a 16.1 percent increase in instantaneous mortality among fish of the 1946 experimental group. Comparison of the growth of normal and marked lake trout fingerlings held in the same ponds indicates that removal of the dorsal and adipose fins (1944), right pectoral fin (1945), or right pelvic fin (1947) had no effect on the growth of marked fish; the differences had no statistical significance. However, the left pectoral mark used in 1946 appears to have slowed growth of the fish so marked by a small (8.6 millimeters), but statistically significant amount.

Introduction

When the Great Lakes Lake Trout Committee set up a research program in April, 1944, one phase of the investigation called for marking at least 10 percent of all hatchery-reared lake trout fingerlings released in Lake Michigan during 1944, 1945, and 1946. Since approximately 1 million fingerling lake trout were planted annually in Lake Michigan, this plan entailed the marking of 100,000 or more fish each year. The only feasible method of marking such large numbers of fish was by the removal of fins in various combinations.

To measure the effect of fin removal on the experimental fish released in Lake Michigan, several groups of fin-clipped fish from the 1944,

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[1] Contribution from the Michigan Institute for Fisheries Research.

1945, 1946, and 1947[1] markings were held along with companion groups of unmarked fish of the same stocks for controls. Observations of fin regeneration and of growth and survival were recorded for these fish over periods ranging from 2 to 4½ years.

All marking was done in September of each year at the U. S. Fish and Wildlife Service Fisheries Station at Charlevoix, Michigan, and fish for the controlled experiments were assembled there at the same time. The experimental fish were then shipped by tank truck to the state fish hatchery at Marquette, Michigan, and held there in ponds.

DESIGN OF EXPERIMENT

Each year as the fish for release in Lake Michigan (or Huron) were marked, they were held in several hatchery troughs. Each experimental lot of fish was then selected by scapping up equal numbers of fish from each trough to secure the desired total; furthermore, the head, middle, and lower portions of each trough were sampled equally to compensate for possible differences in size of fish at different levels in the troughs. For the mortality-growth experiments in 1944, 2,007 marked and 2,000 unmarked fish were used; but by March, 1945, it was obvious that these numbers were too large for the pond facilities at Marquette. Therefore, both lots were reduced to 1,005. In 1945, 1946, and 1947, each experimental lot was 1,000 fish. The experiments on regeneration of fins were started in 1944 with 1,003 marked fish, which were reduced to 500 in March, 1945. In 1945, 1946, and 1947 the lots were each 500 fish.

Length measurements (millimeters) of fish in the several experimental lots were taken as follows: from the 1944 experiment, at the time the experiment was initiated, 20 percent of the regeneration group and 25 percent of the mortality-growth group were measured; for subsequent checks on the 1944 fish, and for all other lots, all fish were measured.

After the fish were marked in September, each lot was transferred to the Marquette, Michigan, Hatchery. Here they were held in covered troughs inside a heated building until late March or April when they were moved to outside ponds. The mortality-growth experiment and the regeneration experiment were conducted in separate ponds. After considerable predation by birds was noted during the spring of 1945, all experimental ponds were covered by chicken wire.

Examinations of the experimental fish were conducted semi-annually each year in March and October through 1949. Counts and measurements on certain groups were obtained also in May of 1948 and 1949. At each examination, all fish were sorted, counted, measured individually, and weighed in groups. Daily mortality records for the various experimental groups were kept by the staff of the Marquette Hatchery. At

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[1] The 1944, 1945, and 1946 plantings were made in Lake Michigan; the 1947 planting, in Lake Huron.

TABLE 1.—*Summary of growth in length and weight of fingerling lake trout in regeneration experiments.*[1] *Average lengths are given in millimeters, average weights in grams. Numbers in parentheses indicate numbers of survivors at each examination.*

Date of examination	1944		1945		1946		1947	
	Average length	Average weight	Average length	Average weight	Average length	Average weight	Average length	Average weight
September, 1944	73.5	3.2(1,003)	......	....	......	....	......	....
March, 1945[2]	93.7	4.8(500)	......	....	......	....	......	....
September, 1945	......	....	82.5	4.7(499)	......	....	......	....
October, 1945	167.4	39.6(255)	......	....	......	....	......	....
March, 1946	188.5	53.1(251)	107.5	9.1(492)	......	....	......	....
September, 1946	......	....	......	....	82.2	4.1(500)	......	....
October, 1946	......	....	175.2	39.0(328)	......	....	......	....
March, 1947	......	....	191.7	50.3(294)	107.6	8.6(488)	......	....
September, 1947	......	....	......	....	......	....	74.3	2.9(500)
October, 1947	......	....	......	....	165.7	29.5(259)	......	....
March, 1948	......	....	......	....	192.3	57.7(175)	98.4	6.8(483)
October, 1948	......	....	......	....	......	....	182.4	51.7(405)
March, 1949	......	....	......	....	......	....	200.5	58.1(390)
October, 1949	......	....	......	....	......	....	246.9	121.1(234)

[1] Fins marked: 1944, dorsal and adipose; 1945, right pectoral; 1946, left pectoral; 1947, right pelvic.
[2] Concerning the number of fish in this lot, see text.

the time of marking and at all subsequent examinations when the fish were measured, they were anesthetized with ether, using one-quarter ounce of ether per quart of water.

OBSERVATIONS ON FIN REGENERATION

In order to determine the efficiency of the mark, a number of marked fish were held separately each year and examined at intervals to determine the extent of regeneration. These fish were examined individually at the time of measurement and graded visually on the basis of no regeneration, ¼ regeneration, ½ regeneration, ¾ regeneration, or full regeneration (the latter were either fins completely missed or only partly removed in the clipping operation). Grading was done with frequent reference to normal fins of unmarked lake trout, and the estimated grade was applied regardless of what portion of the fin was regenerated. The regeneration-control groups were held for at least 18 months, by which time the process of regeneration appears to have reached a level of negligible increase. When the percentage of recognizable specimens remained more or less constant in two consecutive examinations, that group of regeneration control fish was planted out in order to utilize pond space for new experiments. The general growth history of fish in the various regeneration experiments is given in Table 1.

In the 1944 experiment, in which the dorsal and adipose fins were clipped, 13 months elapsed between marking (September, 1944) and the first examination to classify extent of regeneration (October, 1945), when 254 of the 255 survivors were checked (Table 2). As the 1944 mark involved two fins, there were 25 possible combinations of regener-

TABLE 2.—*Summary of observations on fin regeneration among dorsal-adipose clipped lake trout fingerlings held at Marquette Hatchery. Initiated September, 1944, with 1,003 marked fish with average length of 73.5 millimeters, average weight of 3.2 grams.*

Regeneration of fin		Date of observation.			
		October 5, 1945		March 13, 1946	
Dorsa	Adipose	Number of fish with combination	Percentage of total present with combination	Number of fish with combination	Percentage of total present with combination
None	None*[1]	121	47.6	129	51.4
	¼*	21	8.2	16	6.4
	½*	2	0.8	1	0.4
	¾	3	1.2	...	0.0
	Full	2	0.8	3	1.2
¼	None*	38	14.9	40	15.8
	¼*	24	9.4	18	7.2
	½*	4	1.7	1	0.4
	¾	2	0.8	...	0.0
	Full	...	0.0	1	0.4
½	None*	5	1.9	12	4.8
	¼*	10	3.9	7	2.8
	½*	6	2.4	3	1.2
	¾	...	0.0	2	0.8
	Full	...	0.0	...	0.0
¾	None	3	1.2	3	1.2
	¼	3	1.2	3	1.2
	½	1	0.4	...	0.0
	¾	...	0.0	...	0.0
	Full	...	0.0	...	0.0
Full	None	4	1.7	4	1.6
	¼	...	0.0	1	0.4
	½	...	0.0	...	0.0
	¾	...	0.0	...	0.0
	Full	5	1.9	7	2.8
Totals		254[2]	100.0	251	100.0

[1] Stars indicate the nine most easily recognized combinations.
[2] One fish escaped, not graded or measured.

ation. Of the 17 combinations observed (Table 2), the 9 most easily recognized constituted the 231 fish or 90.9 percent of the total number examined in October, 1945.

When the same group was graded again in March, 1946, 251 fish were present. Of this number 227, or 90.4 percent of the total survivors, had ½ or less regeneration. Since there had been little change in the amount of regeneration observed on these two examinations, this experiment was discontinued. It is felt that marked fish with no greater regeneration than is represented in these groups will be identifiable in the future by anglers, commercial fishermen, and fishery investigators.

Four hundred ninety-nine (499) right pectoral-clipped lake trout fingerlings from the fall marking were set aside for observation in September, 1945. This group and all subsequent regeneration groups

TABLE 3.—*Summary of observations on right pectoral fin regeneration experiment. Initiated September, 1945, with 499 marked fish, average length 82.5 millimeters, average weight 4.7 grams.*

Date of examination	Number surviving	Average total length (millimeters)	Range in total lengths	Number (and percent of total surviving) with indicated amount of regeneration				
				0	¼	½	¾	full
March, 1946.......	492	107.5	84—130	474 (96.4)	12 (2.4)	3 (0.6)	2 (0.4)	1 (0.2)
October, 1946.....	328	175.2	105—218	257 (78.4)	47 (14.3)	11 (3.4)	6 (1.8)	7 (2.1)
March, 1947.......	294	191.7	145—234	233 (79.2)	40 (13.6)	11 (3.7)	7 (2.3)	3 (1.2)

were examined at an earlier date in their growth history than were the 1944 fish. The data on regeneration among the marked fish for the 1945 experiment are given in Table 3, which shows the percentage of the surviving fish in each of the five arbitrary classes of regeneration. The percentages of surviving fish with the observed amounts of fin regeneration for the 1946 and 1947 marks are contained in Tables 4 and 5.

SIGNIFICANCE OF REGENERATION EXPERIMENTS

On the basis of regeneration observed among the various fin marks it is obvious that some adjustments should be made in future calculations involving the numbers of recognizable marked fish available from any marking. Table 6 summarizes the extent of regeneration for the four different marks after it appeared that the amount of regeneration had ceased to increase.

The data in Table 6 indicate that between 86 and 93 percent (95 percent confidence range, Snedecor, 1948) of the 1944 dorsal-adipose-marked survivors are recognizable and between 94 and 98 percent of

TABLE 4.—*Summary of observations on the 1946 (left pectoral fin) regeneration experiment. Initiated September, 1946, with 500 marked fish, average length 82.2 millimeters, average weight 4.1 grams.*

Date of examination	Number surviving	Average total length (millimeters)	Range in total lengths	Number (and percent of total surviving) with indicated amount of regeneration				
				0	¼	½	¾	full
March, 1947.......	488	107.6	87—134	339 (69.4)	118 (24.1)	19 (3.8)	8 (1.6)	4 (1.1)
October, 1947.....	259	165.7	122—210	106 (40.9)	87 (33.8)	40 (15.4)	15 (5.7)	11 (4.2)
March, 1948.......	175	192.3	148—284	76 (43.5)	53 (30.3)	28 (16.0)	9 (5.1)	9 (5.1)

TABLE 5.—*Summary of observations on 1947 (right pelvic fin) regeneration experiment. Initiated September, 1947, with 500 marked fish, average length 74.3 millimeters, average weight 2.9 grams.*

Date of examination	Number surviving	Average total length (millimeters)	Range in total lengths	Number (and percent of total surviving) with indicated amount of regeneration				
				0	¼	½	¾	full
March, 1948	483	98.4	83—117	52 (10.8)	211 (43.7)	149 (30.9)	64 (13.2)	7 (1.4)
October, 1948	405	182.4	138—232	35 (8.6)	117 (28.9)	111 (27.4)	77 (19.0)	65 (16.1)
March, 1949	390	200.5	135—254	42 (10.8)	94 (24.1)	98 (25.1)	75 (19.2)	81 (20.8)
October, 1949	234	246.9	175—305	11 (4.7)	78 (33.3)	61 (26.1)	45 (19.2)	39 (16.7)

the 1945 right pectoral-marked lake trout fingerlings surviving have ½ or less regeneration. The survivors bearing the 1946 mark (left pectoral fin clipped) contain between 84 and 94 percent with ½ or less regeneration. It would appear then that the fin-clip combinations used on the Lake Michigan plantings were applied with reasonable efficiency, since approximately 90 percent or more of the survivors carried marks that could be recognized with ease.

The right pelvic mark applied to the 1947 plantings of lake trout fingerlings in Lake Huron did not give such satisfactory results. In this experiment only 64.1 percent of the survivors were in those classes with ½ or less regeneration (95 percent confidence limits, 58-70 percent). There appear to be two reasons for the comparative inefficiency of this mark. First, the time schedule for the 1947 marking and planting operation was such that too few technicians had to mark too many fish in too short a time, and second, the size, shape, and visibility of the pelvic fins on lake trout fingerlings of the lengths handled made it difficult to determine whether or not a clean operation was performed.

Slater (1949), studying fin regeneration in king salmon fingerlings, was able to demonstrate slight statistical correlation between quality of

TABLE 6.—*Summary of pertinent statistics on percentage of regeneration of 1944, 1945, 1946, and 1947 fin marks used on lake trout fingerlings.*

Year of marking	Fins removed	Number of survivors at last check	Percentage of survivors showing ½ regeneration or less	95 percent confidence range for percentage of survivors showing ½ regeneration or less (from Snedecor)[1]
1944	Dorsal and adipose	251	90.4	86—93
1945	Right pectoral	294	96.5	94—98
1946	Left pectoral	175	89.8	84—94
1947	Right pelvic	234	64.1	58—70

[1] There is one chance in 20 that another sample would lie outside the indicated percentages.

pelvic marks and length of fish. He felt that the correlation noted was not caused by the greater regenerative capacity of small fish, but was a result of difficulty in seeing and removing small, transparent fins in a clean manner.

Armstrong (1949), working with marked lake trout fingerlings, has reported that for the dorsal-adipose marking approximately 95 percent of 487 survivors of 500 marked fish at the end of 10 months of observation had ½ or less regeneration. This result is in general agreement with those noted here.

The results of the regeneration experiments have an important bearing on the interpretation of the data obtained from the experiments concerned with comparative mortality. For example, it was found that various percentages of marked fish in the regeneration experiments were missed entirely in the clipping operation, or their fins were completely regenerated. Since a sincere effort was made to draw both experimental groups at random from the stock of marked fish, it seems reasonable to assume that the percentage of completely regenerated fins should be the same among the marked fish of the mortality-growth control experiments as was found in the regeneration control group for the same year and mark.

To illustrate with an example from the data, the regeneration group and the mortality-growth experiment fish from 1944 at the March, 1946, examination can be considered. There were 251 regeneration-control fish alive, of which 7 or 2.8 percent bore fully regenerated dorsal and adipose fins (or these fins were missed in the clipping operation). This observation suggests that of the 660 mortality-growth experiment fish surviving, the 296 fish classed as marked represent only 97.2 percent of the marked fish alive and present, and that actually there were 305 marked fish among the 660 counted $(\frac{296}{0.972})$. Thus the corrected figures for this particular examination would be 355 unmarked fish, 305 marked fish.

For the dates of examinations where the percentages of total regeneration could be applied to the companion mortality-growth experiments, the mortality data have been corrected by the observed percentages of regeneration for those dates. However, the regeneration experiments were not run as long as the mortality experiments, and after the regeneration experiments were discarded, the last percentage of regeneration observed was applied to any further observations on survival. In the following discussion of comparative survival, the observed data will be corrected in the manner just described.

Comparative Survival of Normal and Fin-clipped Fingerlings

For each mark used an equal number of marked and normal fish of approximately the same average size were confined together to determine any differences in survival between marked fish and normal fish. This group also permitted a comparison of the average growth of marked

TABLE 7.—*Numbers of normal (N) and marked (M) lake trout fingerlings surviving at various dates from the mortality-growth control experiments of 1944, 1945, 1946, and 1947, and the calculated distribution of survivors when corrected by known amounts of total fin regeneration.*

Item	Mark and Year															
	1944: dorsal-adipose				1945: right pectoral				1946: left pectoral				1947: right pelvic			
	Observed[2]		Calculated[3]		Observed		Calculated		Observed		Calculated		Observed		Calculated	
	N	M	N	M	N	M	N	M	N	M	N	M	N	M	N	M
At start March, 1945[1]	2,000 1,398	2,007 1,447	2,000 1,398	2,007 1,447 (0.68)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000 ......
October, 1945	407	336 (1.9)	400	343 (4.37)	......	......	......	......	......	......	......	......	......	......	......	......
March, 1946	364	296 (2.8)	355	305 (0.00+)	949	978 (0.2)	941	986 (1.05)	......	......	......	......	......	......	......	......
October, 1946	325	273 (2.8)	317	281 (0.15)	900	860 (2.1)	882	878 (1.15)	......	......	......	......	......	......	......	......
March, 1947	317	262 (2.8)	309	270 (0.03)	885	837 (1.2)	870	852 (0.11)	935	945 (1.1)	924	956 (0.54)	......	......	......	......
October, 1947	278	228 (2.8)	271	235 (0.01)	615	599 (1.2)	608	606 (0.09)	475	396 (4.2)	458	413 (4.11)	......	......	......	......
March, 1948	254	218 (2.8)	248	224 (0.20)	492	472 (1.2)	486	478 (0.04)	349	289 (5.1)	333	305 (0.04)	953	965 (1.4)	939	979 (0.83)
May, 1948	......	......	......	......	429	378 (1.2)	424	383 (1.46)	......	......	......	......	......	......	......	......
October, 1948	239	200 (2.8)	233	206 (0.05)	......	......	......	......	267	196 (5.1)	257	206 (2.04)	877	794 (16.1)	725	946 (19.57)
March, 1949	235	198 (2.8)	229	204 (0.01)	......	......	......	......	240	171 (5.1)	231	180 (0.08)	837	810 (20.8)	......	[4]
May, 1949	228	189 (2.8)	223	194 (0.06)	......	......	......	......	......	......	......	......	......	......	......	......
October, 1949	......	......	......	......	......	......	......	......	212	150 (5.1)	204	158 (0.00+)	621	564 (16.7)	508	677 (0.13)

[1] Fin regeneration not checked in March, 1945. Observed numbers reduced to 1,005 in each category.

[2] Under "Observed, M" in parentheses is given known percentage of total fin regeneration. See last columns, Tables 2, 3, 4, and 5.

[3] In parentheses under "Calculated" are given chi-square values for corrected distribution.

[4] Here an obvious and unexplainable discrepancy occurs. There is a suggestion either that not all experimental fish were collected in October, 1948, or that there were some unexplainable additions after that date.

and normal fish. The groups for the various years were kept together for the duration of the experiments, and all factors causing mortalities should have operated equally on marked and normal fish. If marking is not a factor in mortality, the survivors of both groups should occur in the same ratio of normal fish:marked fish that was established at the initiation of the experiments. However, since it has been demonstrated in the previous section that various percentages of the surviving marked fish completely regenerate their marks and are not recognizable as marked fish, the comparative survival data logically should be adjusted to take this fact into account. The changes that occur when correction for complete regeneration is made are shown in Table 7 which lists both observed and corrected data for the experiments on the four different marks. The corrected ratios were then tested for significance by applying the chi-square test as outlined by Snedecor (1948).

$$\text{Chi-square} = X^2 = \frac{(a - r\,b)^2}{r\,(a + b)}$$

Where: a = observed number of normal fish
b = observed number of marked fish
r = expected ratio of normal fish to marked fish

The chi-squares so obtained, unadjusted for bias due to small numbers, were not deemed to be significant unless they exceed 3.841 (Snedecor, 1948). The occurrence of significant values suggests that marking has led to increased mortality, assuming that unmarked fish did not experience the greater rate of mortality.

It appeared desirable to learn what changes might occur between examinations, as well as to note the cumulative effect of marking through the entire course of the experiments. In following this procedure, the expected ratio of normal fish:marked fish for any date of examination was that observed on the previous examination. Actually each examination constituted a new experiment with the survival ratio of the previous examination being the basis for the determination of the expected ratio of normal fish:marked fish.

The cumulative effect of the marking operation was determined by comparison of the ratio of normal fish:marked fish originally established to the observed data of the last examination to determine chi-square values.

Dorsal-adipose mark, 1944.—In the 1944 experiment, between September, 1944, and March, 1945, marking had no effect on survival (chi-square = 0.68), as more marked fish than normal specimens were alive. However, from March, 1945, to October, 1945, a chi-square had the significant value of 4.37. From October, 1945, through May, 1949, chi-square values ranged between 0.00+ and 0.20. For the entire period of observation (September, 1944, to May, 1949), a chi-square value of 2.12 is obtained. Since the only significant value of chi-square occurred in one of the periodic examinations, it was concluded that the dorsal-adipose mark did not lower the survival of fish so marked.

Right pectoral mark, 1945.—The chi-square values obtained for the corrected observations on comparative survival of fish with the right-pectoral mark were insignificant through the entire course of the experiment. These values ranged between 0.04 and 1.46, and the value calculated over the total period (September, 1945, to May, 1948) of the experiment was 2.08. The right-pectoral mark, therefore, appears not to have affected the survival of the fish so marked.

Left pectoral mark, 1946.—The removal of the left pectoral fin, when compared with the clipping of the companion fin on the other side, yielded entirely different results. The chi-square value obtained for the March, 1947, observation (0.54) suggests that during the period (September, 1946, to March, 1947) the mark had no effect on the survival of the marked fish.

A significant chi-square value was obtained for the October, 1947, observations (4.11), suggesting that the survival of marked fish was adversely affected by marking during the period March, 1947, to October, 1947. From October, 1947, to October, 1949, the chi-square values were not significant, indicating that after October, 1947, marking was not a factor in the survival of marked fish. Chi-square values ranged between 0.00+ and 2.04. However, over the course of the entire experiment (September, 1946, to October, 1949) a chi-square value of 5.85 was obtained. Since a lesser number of marked fish were present at the last check, the significant value noted indicates that the left-pectoral mark had an adverse effect on the survival of fish so marked. Why the removal of the left pectoral fin should have a more deleterious effect on the survival of marked fish than the right pectoral fin is unexplainable at present.

Right pelvic mark, 1947.—Chi-square values calculated on the corrected observations for this experiment were non-significant except for the October, 1948, examination, at which time a significant value in favor of marked fish was noted. Calculated numbers of marked fish present exceeded the calculated numbers of normal fish alive at all examinations. This suggests that removal of the right pelvic fin was not a factor in the mortality of fish marked in 1947.

Some rather glaring and unexplainable discrepancies occur in the data for this year's experiment in the October, 1948, and/or the March, 1949, observations. However, observed and calculated data in all other examinations followed the trends of the other experiments.

Discussion of Comparative Survival

Of the four marks tested, it is concluded that the dorsal and adipose mark, the right pectoral mark, and the right pelvic mark have not had any significant effect on the survival of the lake trout fingerlings to which these marks have been applied. The left pectoral mark, although not affecting survival of fish on which this fin was removed during the first 6 months after marking, apparently was the cause of significant mortalities over the entire period of the experiment. The increase in instantaneous mortality caused by this mark may be measured in a manner suggested by Ricker (1949). Using the tables in Ricker (1948, pp. 98-101), and assuming the corrected results of the last observation in October, 1949, to be the best measure of survival, the corrected data indicate that 20.4 percent of the normal fish survived as compared with 15.8 percent of the marked fish. Corresponding instantaneous mortality rates, as determined from Ricker's table, are 1.589 and 1.845. The difference, 0.256, divided by the value observed for the normal fish, 1.589, suggests that marking increased the instantaneous mortality 16.1 percent, or about 1/6.[1] More recently, Radcliffe (1950) has shown rather conclusively that fin removal did not affect the "cruising speed" (as defined by Fry and Hart) of goldfish or coho salmon fry. Although none of the fin combinations he used were the same as those utilized in the lake trout experiments, the fact that he could find no statistical significance between the cruising rates of normal and marked fish in his experiment suggests the possibility that the same results might be obtained with the various fin combinations used on the lake trout. As Radcliffe points out, fin removal probably affects the fish's ability to swim steadily only slightly but it probably has noticeable effects on the equilibrium, particularly in starting, stopping or turning, or in combination of these maneuvers.

COMPARATIVE GROWTH OF NORMAL AND MARKED FISH

The data on comparative growth of marked and normal fish have not been treated statistically[2] in their entirety because of the voluminous amount of tabulation involved, and also because the differences between average total lengths of marked and normal fish at all times were relatively small. However, statistical analyses were made on each group of fish at the start of the various experiments and on the measurements of the survivors at the last examination. In all but one experiment (1944), the last measurement also was the one which revealed the greatest difference between the average sizes. In the 1944 experiment, the March, 1948, data were also examined statistically (Table 8).

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[1] Instantaneous mortality is defined by Ricker *(loc. cit.)* as the number of fish which would die from a given cause during the year if recruitment were to exactly balance total mortality from day to day.

[2] The formulas used in the statistical analyses were as follows:

$$M = \Sigma X/n$$

$$\text{Standard deviation} = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n - 1}}$$

$$\text{Standard error of mean} = \frac{\text{Standard deviation}}{\sqrt{n}}$$

$$\text{Standard error of the difference} = \sqrt{(S.E._1)^2 + (S.E._2)^2}$$

$$\text{"t"} = \frac{\text{Difference between means}}{\text{Standard error of the difference}}$$

TABLE 8.—*Summary of average total length and number of survivors observed at the various examinations of the normal and marked lake trout fingerlings confined under identical conditions in 1944, 1945, 1946, and 1947. Total lengths are given in millimeters; numbers of survivors appear in parentheses.*

Date of examination	Year							
	1944		1945		1946		1947	
	Normal	Dorsal-adipose	Normal	Right pectoral	Normal	Left pectoral	Normal	Right pelvic
September, 1944....	74.6 (2,000)	73.5 (2,000)	....	....	....	....	....	....
March, 1945[1]......	93.4 (1,005)	93.6 (1,005)	....	....	....	....	....	....
September, 1945....	....	....	82.0 (1,000)	81.5 (1,000)	....	....	....	....
October, 1945......	164.9 (407)	162.4 (336)	....	....	....	....	....	....
March, 1946.......	185.5 (364)	184.1 (296)	106.4 (949)	105.6 (978)	....	....	....	....
September, 1946....	....	....	....	....	80.6 (1,000)	81.9 (1,000)	....	....
October, 1946......	261.0 (325)	256.2 (273)	169.5 (900)	169.2 (860)	....	....	....	....
March, 1947.......	274.9 (317)	272.1 (262)	185.6 (885)	185.2 (837)	103.5 (935)	104.3 (945)	....	....
September, 1947....	....	....	....	....	....	....	73.1 (1,000)	73.8 (1,000)
October, 1947......	339.8 (278)	335.6 (228)	245.2 (615)	245.3 (599)	162.4 (475)	161.4 (396)	....	....
March, 1948.......	368.6 (254)	362.0 (218)	276.8 (492)	278.0 (472)	192.1 (349)	191.9 (289)	97.5 (953)	97.8 (965)
May, 1948.........	....	....	295.4 (429)	298.2 (378)	....	....	....	....
October, 1948......	422.0 (239)	422.2 (200)	....	....	258.9 (267)	256.6 (196)	173.8 (877)	174.8 (794)
March, 1949.......	438.7 (235)	437.8 (198)	....	....	284.6 (240)	286.2 (171)	194.3 (837)	195.2 (810)
May, 1949.........	451.4 (228)	455.4 (189)	....	....	....	....	....	....
October, 1949......	....	....	....	....	343.9 (212)	335.3 (150)	234.9 (621)	236.5 (564)

[1] It was apparent at this date that this group was too large for the pond space available. The actual number of survivors was 1,398 normal, 1,447 marked. The experiment was reduced to 1,005 each and measurements taken on the latter number.

In the 1944 dorsal-adipose-mark control experiment on growth (Table 8), which was held under observation for 4 years and 8 months, the unmarked control specimens grew in average total length from 74.6 to 451.4 millimeters; marked fish grew in average total length from 73.5 to 455.4 millimeters. The greatest difference noted in average size at any examination was in March, 1948, when the average length of the normal fish was 368.6 millimeters and that of the marked fish was 362.0, or 6.6 millimeters less. At all other examinations the differences in average total lengths ranged between 0.1 and 3.8 millimeters in favor of normal fish.

As shown in Table 9 statistical analyses of the length data for this experiment at the start in September, 1944, March, 1948, and May, 1949, resulted in "t" values of 1.556, 1.723, and 0.976 respectively. From unpublished tables furnished by Dr. E. L. Cooper it can be estimated

TABLE 9.—*Statistical analysis of differences in average total length of marked and normal lake trout fingerlings at start and end of experiments. (The percentage chance that the means are different is given in parentheses under the "t" value.)*

Year and mark	Date checked	Type of fish	Range in total length (millimeters)	Number of fish in sample	M (average length in millimeters)	Standard deviation	Standard error of M	Difference between M's	Standard error of difference	"t"
1944 dorsal and adipose	September, 1944	marked	45—105	500	73.5	11.25	0.50	1.1	0.71	1.556
		normal	47—101	500	74.6	11.16	0.50			(88)
	March, 1948	marked	205—472	218	362.0	42.02	2.85	6.6	3.83	1.723
		normal	282—480	254	368.6	40.87	2.56			(91)
	May, 1949	marked	313—563	189	455.4	41.73	3.03	4.0	4.10	0.976
		normal	321—601	228	451.4	41.61	2.76			(67)
1945 right pectoral	September, 1945	marked	55—110	1,000	81.5	9.03	0.29	0.5	0.38	1.316
		normal	54—105	1,000	82.0	8.01	0.25			(81)
	May, 1948	marked	231—391	378	298.2	31.75	1.63	2.8	2.20	1.273
		normal	163—376	429	295.4	30.73	1.48			(80)
1946 left pectoral	September, 1946	marked	63—104	1,000	81.9	6.78	0.21	1.3	0.29	4.482
		normal	61—108	1,000	80.6	6.20	0.20			(100)
	October, 1949	marked	218—446	150	335.3	46.06	3.76	8.6	4.43	1.941
		normal	238—449	212	343.9	33.87	2.33			(94)
1947 right pelvic	September, 1947	marked	56— 90	1,000	73.8	5.05	0.16	0.7	0.25	2.800
		normal	54— 91	1,000	73.1	5.86	0.19			(99)
	October, 1949	marked	164—304	564	236.5	27.40	1.15	1.6	1.59	1.006
		normal	160—303	621	234.9	27.32	1.10			(68)

that these values represent percentage chances of 88, 91, and 67, respectively, that the average sizes of marked and normal fish are different. Since the 95 percent level of probability was not reached at any time it seems logical to conclude that the marked and normal fish did not differ significantly in average size at any time during the experiment. It is concluded that the application of the dorsal-adipose mark had no effect on the growth of the lake trout fingerlings, at least over the 4 years and 8 months of observation.

The right pectoral-mark control experiment of 1945 concerning comparative growth was conducted for a period of 2 years and 8 months. In this time, normal fish grew in average total length from 82.0 to 295.4 millimeters, while the average length of the marked lake trout fingerlings increased from 81.5 to 298.2 millimeters. The differences in average total length between normal and marked fish at any examination were very minutely in favor of the normal fish, ranging from 0.1 to 0.4 millimeter, except at the May, 1948, check when marked fish were 2.8 millimeters larger in average size.

Statistical analyses of the September, 1945, length measurements on the control fish and again at the last examination of the survivors in May, 1948, indicate that the average lengths of the marked and normal lake trout fingerlings were so closely alike as to be regarded as drawn from the same stock. The "t" values were: September, 1945, 1.316; May, 1948, 1.375. The percentage chance that the means were different were 81 and 83 percent respectively, not very close to a 95 percent level of probability. It is concluded that the application of the right pectoral mark to the lake trout fingerlings had no effect on the growth of the fish to which this mark was applied.

The growth control experiment on the 1946 (left pectoral) mark lasted 3 years and 1 month. The unmarked fish grew from 80.6 to 343.9 millimeters in average total length while the marked counterparts were increasing in average length from 81.9 to only 335.3 millimeters. The differences in average size between normal and marked fish at any examinations of this group ranged between 0.3 and 8.6 millimeters.

At the initiation of this experiment it can be demonstrated that the marked fish were significantly larger than the normal fingerlings, although the difference between the average sizes was only 1.3 millimeters. The resulting "t" value found was 4.482—a virtual certainty that the means are different. The left-pectoral-marked fish held their advantage through the March, 1947, examination. Reference to Table 8 will show that the normal fish had a slightly larger average size at the examinations of October, 1947, March, 1948, and October, 1948, but that marked fish had a slight advantage in average size in March, 1949. At the last examination in October, 1949, normal fish had an average size of 343.9 millimeters as compared with an average size of 335.3 millimeters for the marked fish—a difference of 8.6 millimeters in favor of normal fish. Statistical examination of the length data on the last date gives a "t" value of 1.941 or a percentage chance of 94 that the two means are different. This suggests that the left pectoral mark has very likely reduced the growth of the lake trout fingerlings so marked by a small but significant amount.

Measurements on the 1947 growth-control experiment (right pelvic fin removed) at four intervals over 2 years and 1 month indicate that the average length of normal fish increased from 73.1 to 234.9 millimeters while that of the marked fish grew from 73.8 to 236.5 millimeters. At all times the marked fish in this experiment were from 0.3 to 1.0 millimeter larger than the normal specimens in average size.

In this group of experimental fish, examination of the data demonstrates that the marked fish were significantly larger in September, 1947, at the start, even though the difference between the means was only 0.7 millimeter ("t" of 2.800 yielding a percentage chance of 99 that the means are different). At all examinations the average size of the marked fish was greater than the average size of the normal fish. Statistical analysis of the length data from the October, 1949, check yields a "t" value of 1.006—a percentage chance of 68 that the means are different, nowhere near significance levels. It is concluded that the use of the right pelvic mark had no effect on the growth of the fish to which it was applied.

Discussion of Comparative Growth

In three of the four marks tested it should be noted that the "t" values decreased as the fish grew in size and the experiments progressed through time. This trend suggests that as the marked and normal fish from any experiment grew in size there was progressively less significance in the difference between their average sizes. It would appear likely in most instances that within 4 years after marking there would be no significant differences in average sizes between marked and normal fish surviving to that time.

In the one instance where the calculated "t" value was highest at the last examination (1945 mark-right pectoral clipped), the "t" values found suggested that there was no significant difference between the average sizes of marked and normal fish at any time.

The results of the observations on the control experiments lead to the conclusion that of the four marks applied the left pectoral mark used in 1946 is the only one which may have influenced growth unfavorably. The question arises as to why the clipping of the left pectoral fin should cause the results noted, and not the removal of the right pectoral fin. It might be argued that the results recorded are caused by "experimental error," and that were the experiment involving the left pectoral mark repeated a number of times the opposite conclusions might be reached regarding the effect of marking on growth. However, it should be pointed out that the left pectoral mark apparently had a

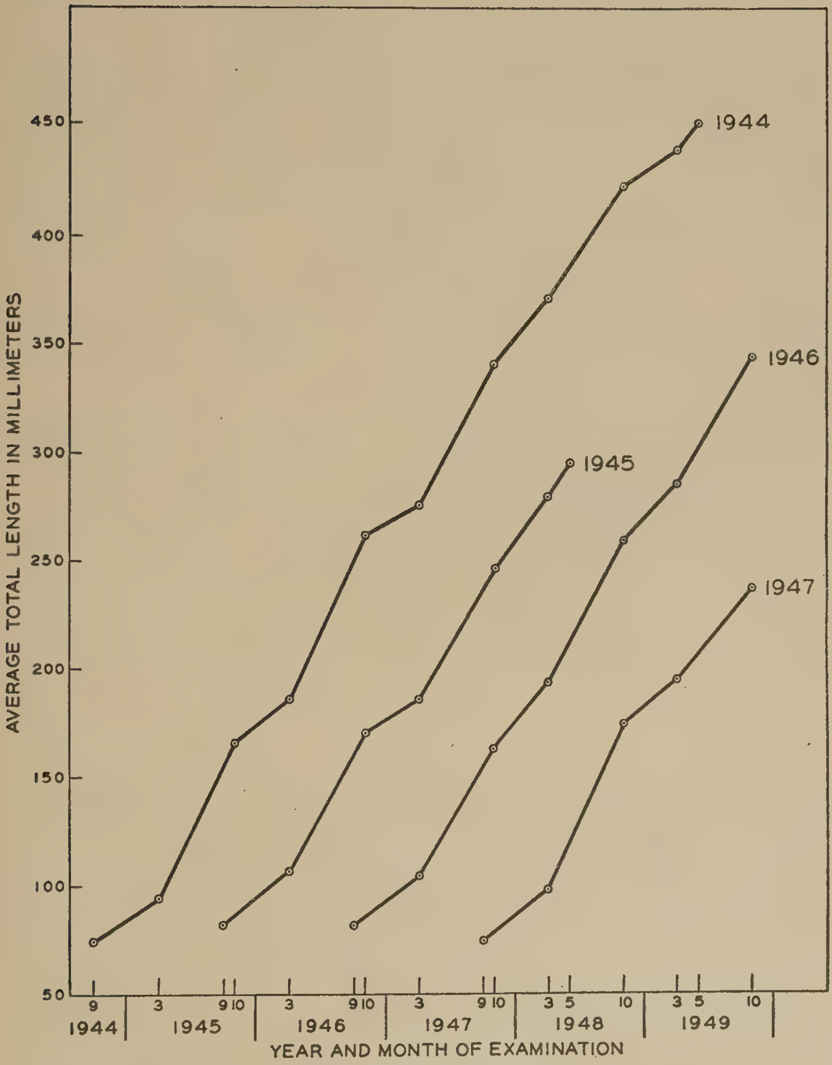

FIGURE 1.—Growth of the unmarked lake trout fingerlings in the mortality-growth control experiments, Marquette Hatchery, Marquette, Michigan.

TABLE 10.—*Summary of comparison of growth in weight of normal and marked lake trout fingerlings for the four mortality-growth control experiments. Average weight in grams for the indicated numbers of survivors is given. Numbers of survivors are indicated in parentheses.*

Date of examination	1944-dorsal-adipose mark		1945-right pectoral mark		1946-left pectoral mark		1947-right pelvic mark	
	Normal	Marked	Normal	Marked	Normal	Marked	Normal	Marked
September, 1944	3.4 (2,000)	3.1 (2,007)	....	....	....	....	....	....
March, 1945¹	5.0 (1,005)	5.1 (1,005)	....	....	....	....	....	....
September, 1945	....	....	4.8 (1,000)	4.6 (1,000)	....	....	....	....
October, 1945	38.0 (407)	35.8 (336)	....	....	....	....	....	....
March, 1946	48.5 (364)	52.5 (296)	²	²	....	....	....	....
September, 1946	....	....	....	....	4.0 (1,000)	4.0 (1,000)	....	....
October, 1946	139.3 (325)	136.1 (273)	38.1 (900)	37.6 (860)	....	....	....	....
March, 1947	154.2 (317)	149.7 (262)	43.7 (885)	43.9 (837)	7.3 (935)	7.3 (945)	....	....
September, 1947	....	....	....	....	....	....	2.9 (1,000)	2.9 (1,000)
October, 1947	326.6 (278)	322.1 (228)	121.6 (615)	121.1 (599)	33.7 (475)	32.3 (396)	....	....
March, 1948	425.5 (254)	402.8 (218)	171.0 (492)	172.8 (472)	54.4 (349)	54.4 (289)	6.7 (953)	6.4 (965)
May, 1948	....	....	217.7 (429)	220.9 (378)	....	....	....	....
October, 1948	626.0 (239)	639.6 (200)	....	....	141.5 (267)	142.4 (196)	43.5 (877)	42.6 (794)
March, 1949	721.2 (235)	725.8 (198)	....	....	191.0 (240)	192.3 (171)	54.0 (837)	55.3 (810)
May, 1949	816.5 (228)	830.1 (189)	....	....	....	....	....	....
October, 1949	....	....	....	....	329.3 (212)	319.3 (150)	100.2 (621)	101.6 (564)

[1] See footnote, Table 8.
[2] Not taken.

statistically significant effect on survival as well as a near-significant effect (if not significant) on growth. It would seem reasonable to assign the results to "experimental error" if the results had been found to be significant in only the mortality analysis or only the growth analysis. The fact that significance or near-significance was noted in the analysis of both growth and survival suggests, on the other hand, that more than chance is involved in the results noted for the experiments involving the left pectoral fin.

The growth data for the unmarked fish listed in Table 8 are portrayed in graphic form in Figure 1. Since the marked fish differed only slightly from the unmarked lake trout only the growth curves for the unmarked fish are given. It is of interest to note that the curves for the four different years are very similar in slope despite the varying numbers present at any one time or surviving to the last examination.

Armstrong (1949) compared the growth of the survivors from 500 dorsal-adipose-clipped lake trout fingerlings and 500 normal lake trout fingerlings held between August, 1947, and June, 1948, at the Provincial Fish Hatchery at Port Arthur, Ontario. He also found no difference between the growth of clipped and unclipped trout.

The data on average weight increases of normal and marked lake trout held for various periods of time are summarized in Table 10. Average weights were obtained by weighing marked and normal fish by groups in water and dividing the total weight by the number present. The inspection of this table suggests that there is little if any difference in the average weights of marked and normal fish held under identical conditions for the same length of time. In all years except 1946, marked fish grew at slightly faster rates than did normal fish, as judged by the average weights of the survivors at the conclusion of the experiments. Statistical comparison of marked and normal fish was not possible because individual weights of fish were not obtained. It is tentatively concluded that marking has no effect on growth in weight.

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STATUS OF THE LAKE TROUT FISHERY IN LAKE SUPERIOR

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Abstract

The production of lake trout in the United States waters of Lake Superior was low (only 1,465,000 pounds) in 1879, the first year for which there is a record. Expansion of the fishery must have started soon thereafter, for the take was 3,488,000 pounds in 1885, the next year for which we have statistics, and averaged 3,416,000 pounds in 1885-1892. The years after 1892 can be divided readily into three general periods with average yields as follows: 1893-1907—4,599,000 pounds; 1908-1925—2,168,000 pounds; 1926-1949—3,049,000 pounds. A take of 3 million pounds can be held as "normal" in the modern fishery. During the three periods just listed the percentage contributions of the individual states to the United States total (as computed from the averages for individual periods) ranged from 65.1 to 71.5 for Michigan, 17.5 to 25.6 for Wisconsin, and from 9.3 to 11.0 for Minnesota.

In the Canadian (Province of Ontario) waters of Lake Superior the average annual output of lake trout rose from 309,000 pounds in 1871-1882 to 900,000 pounds in 1883-1893, 1,567,000 pounds in 1894-1903, and 2,189,000 pounds in 1904-1918. This last period of relatively high yield was followed by two intervals of successively lower average catches—1,691,000 pounds in 1919-1929 and 1,395,000 pounds in 1930-1949.

For the combined United States and Canadian waters of Lake Superior the general trends in the production of lake trout can be described by the following averages: 1879—1,653,000 pounds; 1885-1892—4,325,000 pounds; 1893-1907—6,236,000 pounds; 1908-1949—4,403,000 pounds.

The short-term fluctuations of production during the more recent years give evidence of periodicity in the output of lake trout in Michigan, Ontario, and in the entire lake. Furthermore, these periodic fluctuations tended to be similar in Michigan and Ontario waters. The coefficient of correlation (r) between

production in Michigan and Ontario in 1920-1949 (after elimination of trend in the statistics for both areas) had the significant value of 0.456. This correlation suggests that Michigan and Ontario fishermen exploit a common stock or stocks subject to similar fluctuations.

Statistics on the production of lake trout in 5 of the 6 statistical districts of the State of Michigan waters of Lake Superior (see Fig. 2 for boundaries of the districts) in 1885 suggest that in most areas the fishery was then in the process of development. Even in 1891-1908 when the general level of production was high, there is evidence that during certain periods the catch in some areas was influenced strongly by factors (such as accessibility to market) other than the natural productivity of the waters. Comparisons of the average annual output of lake trout in the individual districts in 1891-1908 and 1929-1943 (the base period for our modern statistical analysis) reveal an enormous decrease in the Whitefish Bay region (S-6) from 916,000 pounds in 1891-1908 to only 177,000 pounds in 1929-1943, a substantial drop (from 655,000 pounds to 385,000 pounds) in the Marquette-Munising area (S-4), and a small decrease (from 141,000 pounds to 138,000 pounds) in the Black River-Ontonagon district (S-2). Among the remaining districts the average yearly take increased from 322,000 pounds in 1891-1908 to 354,000 pounds in 1929-1943 at Isle Royal (S-1), from 428,000 pounds to 501,000 pounds in the Grand Marais district (S-5), and from 422,000 pounds to 506,000 pounds in the Keweenaw area (S-3). These changes in the catch resulted in a westward shifting of production centers. Districts S-1, S-2, and S-3 which together contributed only 30.7 percent of the 1891-1908 catch accounted for 48.4 percent of the take in 1929-1943.

The 1929-1949 production in all districts exhibited periodic fluctuations that were characterized by peaks in the middle 1930's and middle 1940's.

The indices of abundance or availability as computed from records of the catch of lake trout per unit of fishing effort showed periodic fluctuations in all districts of the State of Michigan waters similar to those of production (the peaks and the intervening minima fell a little earlier in the curves of abundance than in the production curves). For the combined districts the abundance of lake trout, expressed as a percentage of the 1929-1943 mean, stood at 108 in 1929, dropped to 100 in 1931, rose to a 21-year high of 137 in 1934, decreased to 80 in 1940, increased again to 107 in 1944 and then fell to the 21-year low of 65 in 1949 (this last decline was interrupted by a small increase in 1947).

The 1929-1949 fluctuations in abundance were similar in the 5 mainland districts (S-2 through S-6). The coefficients of correlation (r) were significant for all 10 pairings and those for the 4 easterly districts (S-3 through S-6) were extremely high ($p < 0.001$ for all 6 values). Thus we have evidence that the fishermen along the mainland exploit common stocks or stocks in which the factors controlling availability are the same or subject to closely similar fluctuations. The fluctuations in abundance in S-1 were correlated significantly ($p < 0.05$) with those in S-2 but otherwise appeared to be independent of conditions along the mainland.

The distinctly cyclic fluctuations that characterized the statistics on production and abundance were much less apparent in the 1929-1949 data on fishing intensity in the State of Michigan districts. In districts S-3, S-4, and S-5 a possible tendency toward a cyclic fluctuation seems to have been obscured by a long-term upward trend that was becoming stronger toward the end of the 21-year period. For the combined districts the level of fishing pressure was consistently high after 1943. Over the 6-year period, 1944-1949, fishing intensity expressed as a percentage of the 1929-1943 mean averaged 142; for the most recent 4 years, 1946-1949 the average intensity index was 151.

On the whole, the 1929-1949 production of lake trout in the State of Michigan waters of Lake Superior was unreliable as an indicator of changes in abundance. The coefficient of correlation between the fluctuations of catch and abundance was, to be sure, positive and significant in S-1 ($p < 0.05$) and

S-6 ($p < 0.01$), but in the remaining districts and for the combined districts the values of the coefficient were far below the level of significance.

The failure of production to serve better as an indicator of changes in abundance can be attributed to the negative correlation that existed between abundance and fishing intensity (values of r highly significant in every district but S-6 and for the combined districts). The relationship suggests that fishermen have increased their fishing pressure in order to maintain their production during the recent years of declining abundance.

The condition of the lake trout fishery of the State of Michigan waters of Lake Superior must be termed unhealthy and the outlook for the future is not good. Production in 1949 stood at 106 percent of the 1929-1943 mean, but this level of yield was made possible only by fishing intensity that was 162 percent of average; the abundance index in 1949 was only 65. Certainly the stocks of lake trout are in a poor state to withstand the threatened inroads of sea lampreys which have been taken from all parts of Lake Superior and are known to have established spawning runs at least as far west as the Keweenaw Peninsula.

INTRODUCTION

Coincident with the spread and increase in the abundance of the parasitic sea lamprey (*Petromyzon marinus*) in Lakes Huron and Michigan the stocks of lake trout (*Salvelinus namaycush*) declined to such a low level as to bring an end to commercial operations directed specifically toward the capture of that species. It is the considered opinion of the investigators of the staff of Great Lakes Fishery Investigations that depredations of the lamprey have been the major, and in all probability the only significant, contributing factor to the catastrophes that have overtaken both lakes. We concede readily that absolute proof of our belief is lacking. On the other hand, the extensive evidence available permits us no other view. A critical evaluation of this evidence does not come within the scope of this paper. Of primary significance in the array, however, are the statistical records (Hile, 1949; Hile, Eschmeyer, and Lunger, 1951) which demonstrate conclusively that overfishing was not, as frequently has been alleged, the cause of the failure of the lake trout fishery in either the United States waters of Lake Huron or the State of Michigan waters of Lake Michigan.

The disappearance of the lake trout fishery in Lakes Huron and Michigan leaves Lake Superior as the only important center of commercial production of the species in the United States, and even in this last stronghold the stocks are in awful danger of early destruction. As yet we have no evidence of extensive damage by the sea lamprey in Lake Superior. On the other hand, adult sea lampreys have been captured in all parts of the lake and the presence of spawning runs has been established as far west as the Keweenaw Peninsula. Since each new lake presents a new and different environment, we cannot attempt to predict the extent or rate of increase in the abundance of sea lampreys in Lake Superior. Conceivably this, the most northerly and the coldest of the Great Lakes, may prove less hospitable than did Lakes Huron and Michigan. It is equally conceivable, unfortunately, that the lake trout fishery may collapse as rapidly in Lake Superior as it did in Lake Michigan where the commercial take dropped more than 90 percent in a brief span of 5 years.

The fisheries of Lake Superior are so constituted that the disappearance of the lake trout would mean an end to the fishing industry as it has existed in the past. In support of this statement, it may be pointed out that during the 5 years 1945-1949 the lake trout, although contributing only 14 to 20 percent of the total production in the United States waters of Lake Superior, brought such high prices as to account for 51 to 60 percent of the total value of the catch. Not only would the disappearance of the lake trout entail the loss of more than half of the cash income of Lake Superior fishermen; it would force discontinuation of much of the fishing now carried on for the capture of lake herring (*Leucichthys artedi*), the principal species from the standpoint of production (72 to 77 percent of the take in 1945-1949, but, because of the low price, only 20 to 32 percent of the value). The great bulk of the lake herring catch is taken within the space of a few weeks in late November and early December. At other times of the season, fishing is directed largely toward the capture of the lake trout. With that species gone, therefore, operations during much of the season would have to be discontinued. It is to be questioned whether many fishermen could afford to maintain their boats, houses, and equipment for the short-term fishery for the cheap lake herring. In all probability most of them would be forced to abandon fishing altogether and turn to other means of livelihood. At best, fishing for lake herring would become small-scale and casual, with most of the present high production lost.

The continuation of fishing for lake whitefish (*Coregonus clupeaformis*), the third important fish in Lake Superior (4 to 7 percent of the catch and 12 to 23 percent of the value in 1945-1949) might be possible for a time in the local areas in which the species is abundant, but even this fishery would be handicapped by the loss of the lake trout ordinarily captured along with the whitefish. Furthermore, experiences in Lakes Huron and Michigan have demonstrated that the whitefish is in no sense immune to attacks by the sea lamprey and that predation on the whitefish increases as the lake trout becomes less plentiful.

In Lake Superior, therefore, we face the prospect of losing the greater part of the present production of fish — a production that normally falls between 15 and 20 million pounds. This loss is not inconsiderable at a period when the maintenance of food production bids fair to become a question of national importance. Furthermore, the effects of the loss on the economies of the many local communities that depend primarily on the fisheries would be disastrous.

MATERIALS AND METHODS

Statistics on the commercial production of lake trout in Lake Superior through 1940 have been adapted from Gallagher and Van Oosten (1943).

TABLE 1.—*Production (thousands of pounds) of lake trout in the commercial fisheries of Lake Superior, 1871-1949.*

Year	State			U. S. total	Canada (Ontario)	Grand total
	Minnesota	Wisconsin	Michigan			
1871	....	....	....	....	169	....
1872	....	....	....	....	227	....
1873	....	....	....	....	300	....
1874	....	....	....	....	337	....
1875	....	....	....	....	191	....
1876	....	....	....	....	679	....
1877	....	....	....	....	607	....
1878	....	....	....	....	98	....
1879	....	....	....	1,465	189	1.653
1880	....	....	....	....	313	....
1881	....	....	....	....	181	....
1882	....	....	....	....	416	....
1883	....	....	....	....	852	....
1884	....	....	....	....	646	....
1885	1,376	785	1,327	3,488	912	4,400
1886	....	....	....	....	842	....
1887	....	....	....	....	703	....
1888	....	....	....	....	971	....
1889	1,099	430	1,838	3,367	1,020	4,387
1890	138	356	2,119	2.613	692	3,306
1891	....	....	2,729	....	1,077	....
1892	....	601	1,998	....	1,056	....
1893	619	1,100	2,622	4,342	1,129	5.471
1894	....	1,102	2,506	....	1,543	....
1895	....	1,500	2,226	....	1,378	....
1896	....	2,000	2,459	....	1,529	....
1897	394	780	2,620	3,794	1,543	5,337
1898	....	....	2,675	....	1,490	....
1899	247	709	2,668	3,625	2,183	5,808
1900	....	....	2,575	....	1,332	....
1901	....	....	3,039	....	1,537	....
1902	....	....	2,478	....	1,377	....
1903	489	1,048	4,055	5,592	1,760	7,352
1904	....	....	4,330	....	2,226	....
1905	....	....	4,101	....	1,984	....
1906	....	....	3,617	....	1,971	....
1907	400	....	2,916	....	1,575	....
1908	215	382	2,306	2,903	1,968	4,871
1909	....	427	....	....	3,156	....
1910	....	260	....	....	3,966	....
1911	....	505	880	....	1,725	....
1912	....	521	938	....	1,588	....
1913	150	856	1,380	2,386	1,842	4,228
1914	105	629	942	1,676	1,576	3.252
1915	86	511	776	1,373	3,610	4,983
1916	137	586	1,455	2,178	1,522	3,699
1917	125	435	1,424	1,983	1,810	3,793
1918	223	441	1,662	2,326	2,319	4,645
1919	242	470	2,752	3,463	1,471	4,934
1920	238	458	1,319	2,016	1,108	3,124
1921	383	501	1,240	2,124	1,176	3,300
1922	236	562	1,376	2,175	1,486	3.660
1923	253	482	1,165	1,901	1,958	3.859
1924	371	557	1,637	2,565	1,711	4,276
1925	345	475	1,834	2,655	1,868	4,522
1926	333	441	2,506	3,280	1,966	5,246
1927	324	534	2,194	3,051	2,197	5,248
1928	391	291	2,280	2,962	1,914	4,876
1929	322	558	1,924	2,804	1,747	4,551
1930	294	475	1,720	2,489	1,530	4,019
1931	536	495	1,961	2,993	1,328	4,321
1932	532	564	1,971	3,067	1,124	4,191
1933	227	560	1,706	2,493	968	3,461
1934	270	611	2,493	3,374	1,261	4,634
1935	379	502	2,596	3,476	1,518	4,994
1936	393	520	2,319	3,233	1,596	4.829
1937	354	440	2,291	3,085	1,699	4,784
1938	463	520	2,184	3,167	1,668	4,835
1939	349	462	1,934	2,744	1,307	4,052
1940	321	513	1,843	2,677	1,261	3,938

TABLE 1.—*Continued*

Year	State			U. S. total	Canada (Ontario)	Grand total
	Minnesota	Wisconsin	Michigan			
1941	353	630	1,871	2,854	1,298	4,153
1942	277	659	2,023	2,959	1,361	4,320
1943	347	618	2,089	3,053	1,323	4,376
1944	332	708	2,700	3,740	1,553	5,292
1945	234	573	2,562	3,369	1,479	4,848
1946	316	534	2,594	3,444	1,531	4,975
1947	219	518	2,226	2,964	1,286	4,250
1948	240	553	2,161	2,954	1,447	4,401
1949	270	514	2,181	2,966	1,356	4,322

Data for United States waters in years after 1940 were compiled in the Great Lakes office of the Fish and Wildlife Service (Michigan) or supplied by state conservation departments (Wisconsin and Minnesota); catch figures for Canadian waters in these same years were obtained from published reports of the Ontario Department of Lands and Forests (formerly the Game and Fisheries Department) or supplied privately by that organization.

Catch statistics for local districts in the State of Michigan waters of Lake Superior in 1885 were taken from Smith and Snell (1891); those for 1891-1908 were compiled (with W.P.A. assistance) from original records made available by the Michigan Department of Conservation. Detailed information on the production and abundance of lake trout and on the intensity of the fishery for the species in the same statistical areas, 1929-1949, was derived from reports of commercial fishing submitted each month by every commercial operator licensed by the State of Michigan, and turned over to us for analysis by the Department of Conservation.

Descriptions of methods employed for the analysis of commercial fishery statistics in the State of Michigan waters of the Great Lakes and examples of the application of the statistics to various fishery problems can be found in papers by: Hile (1937, 1949); Hile and Jobes (1941); Van Oosten, Hile, and Jobes (1946); Hile, Eschmeyer, and Lunger (1951).

Illustrations published in this article were prepared by Mr. Howard J. Buettner.

TRENDS IN THE PRODUCTION OF LAKE TROUT IN LAKE SUPERIOR, 1871-1949

Comments on the trends in the production of lake trout in Lake Superior (Table 1) will be based largely on the averages for selected periods of years (Table 2). It is not intended to imply through this division into periods that the level of the take was stable in any of them. On the contrary, the inspection of Table 1 reveals wide variation in the catch

TABLE 2.—*Average production (thousands of pounds) of lake trout in various areas of Lake Superior in certain periods of years and percentage distribution of the United States catch among the different states.*

Period of years	Item	United States				Canada (Ontario)		Entire lake	
		Minnesota	Wisconsin	Michigan	Total[1]	Period of years	Production	Period of years	Production[1]
1879	Production	....	....	....	1,465	1871—1882	309	1879	1,653
1885—1892	Production	871	543	2,002	3,416	1883—1893	900	1885—1892	4,325
	Percentage	25.5	15.9	58.6	....				
1893—1907	Production	430	1,177	2,992	4,599	1894—1903	1,567	1893—1907	6,236
	Percentage	9.3	25.6	65.1	....	1904—1918	2,189	1908—1949	4,403
1908—1925	Production	222	503	1,443	2,168	1919—1929	1,691	....	....
	Percentage	10.2	23.2	66.6	....				
1926—1949	Production	336	533	2,180	3,049	1930—1949	1,395	....	....
	Percentage	11.0	17.5	71.5	....	....	....	....	....

[1] The totals are the sums of the means as determined for the states (and province in the figures for the entire lake) individually from all data available for each area in the indicated period.

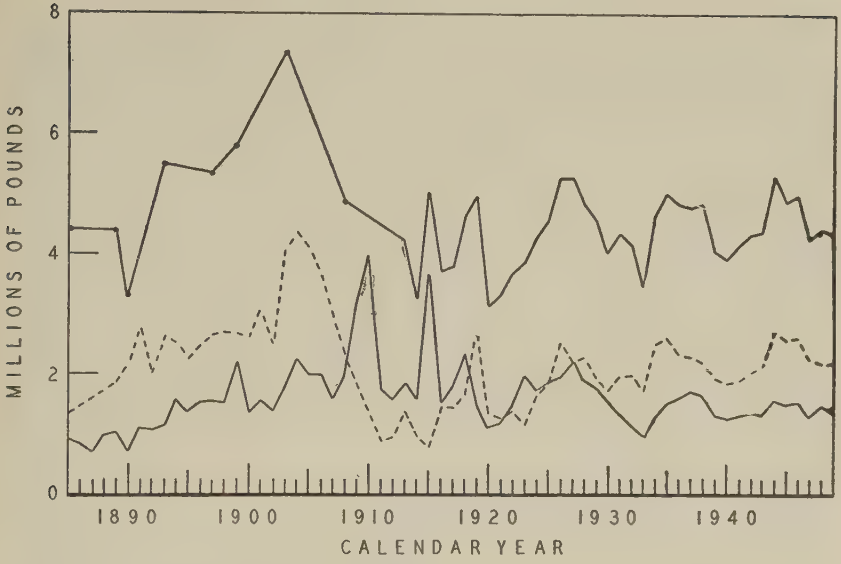

FIGURE 1.—Production of lake trout in Lake Superior, 1885-1949. Province of Ontario, lower solid line; State of Michigan, broken line; entire lake, upper solid line. In the upper curve heavy dots show the scattered individual years prior to 1913 in which catch records were available for the entire lake.

in all periods and a strong tendency toward cyclic fluctuations within some. It is believed, nevertheless, that the data of Table 2 serve adequately the purpose of describing the changes in the general level of yield that have taken place.

United States production.—In 1879, the first year for which we have a record of the output of lake trout in the United States waters of Lake Superior, the take was only 1,465,000 pounds. Presumably the fishery was then still in the earlier stages of development. Data are lacking on the 1879 yield of lake trout in the individual states.

The average production of 3,416,000 pounds in 1885-1892 (see footnote to Table 2 concerning the method of computing the average) was 2.3 times that in 1879. Although the take varied considerably in all states — 1,327,000 to 2,729,000 pounds in Michigan (Fig. 1); 356,000 to 785,000 pounds in Wisconsin; 138,000 to 1,376,000 pounds in Minnesota — the relative fluctuation was by far the greatest in the last named state. Indeed, the abrupt drop from more than a million pounds in 1885 and 1889 to only 138,000 pounds in 1890 gives cause for skepticism as to the reliability of the Minnesota statistics for those years. Michigan contributed well over half (58.6 percent) of 1885-1892 production of lake trout in the United States waters of Lake Superior with Minnesota ranking second (25.5 percent) and Wisconsin third (15.9 percent). If we were to assume that the percentage contribution of Minnesota amounted to only 10 percent (a figure supported by the data for later periods), the catch from that state in 1885-1892 could be estimated at 283,000 pounds; the average for all United States waters would then become 2,828,000 pounds and the percentage contributions of Wisconsin and Michigan would be 19.2 and 70.8 respectively.

The average catch of lake trout in 1893-1907 (4,599,000 pounds) was 1,183,000 pounds greater than that for 1885-1892. The rise can be traced entirely to Michigan and Wisconsin where increases of 990,000 and 634,000 pounds, respectively, exceeded by far the decline of 441,000 pounds in Minnesota. The decrease in the take in Minnesota was accompanied by a decline from 25.5 to 9.3 percent in the contribution of that state to the United States total. At the same time the percentages increased from 15.9 to 25.6 in Wisconsin and from 58.6 to 65.1 in Michigan. The conflict of trends in Minnesota as compared to Michigan and Wisconsin lends additional support to the skepticism expressed in the preceding paragraph concerning the reliability of the Minnesota statistics for the 1885-1892 period.

The variations of production in the individual states in 1893-1907 were also large — 247,000 to 619,000 pounds in Minnesota; 709,000 to 2,000,000 pounds in Wisconsin; 2,226,000 to 4,330,000 pounds in Michigan — but were not of a character to raise suspicion as to the dependability of the statistics. The Michigan data, which are continuous through the period, give a suggestion of a cyclic fluctuation toward the end of the interval, with a maximum in 1904.

Statistics were available for all three states in only 4 of the 15 years of the 1893-1907 period. The extremes of 5,592,000 pounds in 1903 and 3,625,000 pounds in 1899, therefore, probably are not the true maximum and minimum for the interval.

All three states contributed toward the decline of 2,431,000 pounds or 52.9 percent from 4,599,000 pounds in 1893-1907 to 2,168,000 pounds in 1908-1925. The actual and percentage decreases for the individual states were: Minnesota—208,000 pounds, 48.4 percent; Wisconsin—674,000 pounds, 57.3 percent; Michigan—1,549,000 pounds, 51.8 percent. As would be expected from the close similarity among the relative decreases, the percentage contributions of the states to the total changed but little (increases from 9.3 to 10.2 percent and 65.1 to 66.6 percent in Minnesota and Michigan, respectively; decrease from 25.6 to 23.2 percent in Wisconsin).

The ranges of fluctuation in production in the individual states in 1908-1925 were large — 86,000 to 383,000 pounds in Minnesota; 260,000 to 856,000 pounds in Wisconsin; 776,000 to 2,752,000 pounds in Michigan — but again the nature of the variation was not such as to throw doubt on the dependability of the data. Despite the irregularity of the variations of the catch, some indications of cyclic fluctuations are detectable. It might be held, for example, that 1921 in Minnesota, 1913 in Wisconsin, and 1919 in Michigan were peak years in roughly cyclic fluctuations.

Of the 14 years in the 1908-1925 interval for which there are United States totals, the take exceeded 3 million pounds in one (3,463,000 pounds in 1919), was between 2 and 3 million pounds in 9, and fell below 2 million pounds in 4 (smallest yield, 1,373,000 pounds in 1915). These small catches are in strong contrast with those of the preceding period when all four totals were above 3 million pounds and one (that for 1903) exceeded 5½ million pounds.

The average production of lake trout increased in all three states from 1908-1925 to 1926-1949. The actual and percentage increases were: Minnesota—114,000 pounds, 51.4 percent; Wisconsin—30,000 pounds, 6.0 percent; Michigan—737,000 pounds, 51.1 percent. For all United States waters the rise amounted to 881,000 pounds or 40.6 percent. The relatively small increase in Wisconsin led to a decrease in the percentage contribution of that state to the United States total from 23.2 in 1908-1925 to 17.5 in 1926-1949; at the same time these percentages rose from 10.2 to 11.0 in Minnesota and from 66.6 to 71.5 in Michigan.

The 1926-1949 means of 336,000, 533,000, and 2,180,000 pounds for Minnesota, Wisconsin, and Michigan, respectively, and the United States average of 3,049,000 pounds can be accepted as the "modern normal" for Lake Superior. In round figures a take of 3 million pounds of lake trout per year is to be expected in the United States waters of Lake Superior under present-day conditions. Although the total range in the United States catch was fairly large (from 2,489,000 pounds in 1930 to 3,740,000 pounds in 1944 — range of 1,251,000 pounds) the catch deviated from the mean by less than 250,000 pounds in 15 of the 24 years. The ranges of production in the individual states were: Minnesota—219,000 to 536,000 pounds; Wisconsin—291,000 to 708,000 pounds; Michigan—1,706,000 to 2,700,000 pounds.

The catch statistics for the State of Michigan waters reveal a distinct periodicity in the fluctuations of production in 1926-1949. Extended comments on these fluctuations need not be offered here since the figures for most of the period (1929-1949) will be discussed in detail in the next section. Some evidence for cyclic fluctuations is to be found in the statistics for Minnesota and Wisconsin but the periods are less clearly defined than are those in the Michigan data. Cyclic fluctuations are to be noted also in the United States totals. The periods corresponded reasonably well with those for the Michigan statistics --a situation to be expected since Michigan contributed 71.5 percent of the total 1926-1949 output.

Canadian (Province of Ontario) production.—The early period 1871-1882 was one of erratically variable but generally low yields. The mean for the interval was 309,000 pounds and the range was from 98,000 pounds in 1878 to 679,000 pounds in 1876. The fishery obviously was in the early stages of development in 1871-1882.

The expansion of the lake trout fishery in the Canadian waters of Lake Superior seems to have continued through 1883-1893 (see Fig. 1

for graph of production in 1885 and later) during which period the trend of production was definitely, if irregularly, upward. This trend carried the output to more than a million pounds for the first time in 1889; the figure was exceeded again in 1891 and succeeding years. The average take in 1883-1893 (900,000 pounds) was nearly three times that of 1871-1882.

The average production in 1894-1903 (1,567,000 pounds) was 667,000 pounds above that for 1883-1893. The catch did not drop below 1,332,000 pounds (the figure for 1900) and in one year it was above 2 million (2,183,000 pounds in 1899). The fluctuations, though considerable, lacked the upward trend that characterized the preceding period.

The year 1904 introduced a 15-year interval in which the Canadian catch of lake trout in Lake Superior was at a higher level than in any earlier or later period. The average take of 2,189,000 pounds was 622,000 pounds above that for 1894-1903. Much of the increase can be traced to the three exceptional years (1909, 1910, and 1915) in which the output exceeded 3 million pounds (the catch of 3,966,000 pounds in 1910 was the record high for the Ontario waters of Lake Superior). If these three years are excluded, the mean for the period is reduced to 1,842,000 pounds and the increase over 1894-1903 to 275,000 pounds. Further indication of the effect of these three exceptional years is found in the circumstance that the catch was below the 15-year mean — indeed was less than 2 million pounds — in 10 years. The lowest take for the period was 1,522,000 pounds in 1916.

The average yield of lake trout in the Ontario waters of Lake Superior in 1919-1929 (1,691,000 pounds) was a half million (498,000) pounds below that of 1904-1918. The catch was lowest in the earlier years of the period (less than 1½ million pounds in 1919-1922 — minimum of 1,108,000 pounds in 1920). During the last 7 years the take was consistently above 1½ million pounds, and in 1927 it amounted to 2,197,000 pounds, the maximum for the period.

The output of lake trout in Ontario in 1930-1949 fluctuated about the still lower level of 1,395,000 pounds — 296,000 pounds less than the mean for 1919-1929 and 794,000 pounds below the average for 1904-1918. The catch in 1930-1949 was characteristically between 1 and 1½ million pounds (12 of 20 years). It fell below a million pounds in one year (968,000 pounds in 1933) and was more than 1½ million pounds in 7 years. The maximum yield was 1,699,000 pounds in 1937. During both of the more recent periods, 1919-1929 and 1930-1949, the production of lake trout in the Ontario waters of Lake Superior exhibited a tendency toward periodic fluctuations.

Production of the entire lake. -- Because of gaps in the United States data, totals are available for the entire lake for only scattered years prior to 1913. (See Fig. 1 for a graph of the production in 1885-1949.)

In 1879, the first year for which we have a total, low catches in both the United States and Canada led to a combined take of only 1,653,000 pounds for the lake.

The level of yield was distinctly higher in 1885-1892, when the production ranged from 3,306,000 pounds in 1890 to 4,400,000 pounds in 1885 and averaged 4,325,000 pounds (see footnote to Table 2 concerning computation of average). This mean was 2,672,000 pounds above the figure for 1879.

The period 1893-1907 was one of rather consistently high production. The catch of 7,352,000 pounds in 1903 is the highest for which we have a record (the figures for Michigian and Ontario suggest strongly that the take may have been even higher in 1904 and 1905) and in each of three other years for which there is a total the output exceeded 5 million pounds (minimum of 5,337,000 pounds in 1897). The average for the 15 years as estimated from all available statistics was 6,236,000 pounds or 1,911,000 pounds greater than that for 1885-1892.

Despite a considerable total range of variation — from 3,124,000 pounds in 1920 to 5,292,000 pounds in 1944 — and a slight upward trend, no attempt has been made to divide the 1908-1949 interval into shorter periods. The mean catch of 4,403,000 pounds in 1908-1949 was nearly the same as that for 1885-1892 (4,325,000 pounds) but represents a drop of 1,833,000 pounds from the 1893-1907 average of 6,236,-000 pounds. The output of lake trout in all waters of Lake Superior in 1908-1949 was characteristically between 4 and 5 million pounds (in 26 of the 38 years for which there are lake totals). The take exceeded 5 million pounds in 3 years and fell below 4 million pounds in 9 years.

Much of the variation in the production of lake trout in 1908-1949 can be traced to cyclic fluctuations. The tendency toward periodicity was particularly strong during the last 30 years of the period when distinct peaks were reached in 1926-1927, 1935, and 1944 and minimal values occurred in 1920, 1933, and 1940. The last 3 years, 1947-1949, seem to have been part of a period of relatively low yield. The three peaks were spaced about 9 years apart, but the intervals between the minima were unequal (13 and 7 years).

The cyclic fluctuations of the production during the more recent years were distinctly more pronounced for the entire lake than for either of the two major fishing areas, Michigan and Ontario (Fig. 1). This situation was brought about by the similarity of the fluctuations in the two smaller regions — a similarity that tended to accentuate the periodicity when the Michigan and Ontario figures were combined in the computation of totals for the entire lake (these two areas accounted for 80.1 percent of the Lake Superior total in 1930-1949). To some extent the similarities in the production of lake trout in Michigan and Ontario are obscured by differences in the trends in the two areas (noticeably upward in Michigan and slightly downward in Ontario). When these trends were eliminated (through the fitting of straight lines to the data) the coefficient of correlation between the catch in Michigan and Ontario over the 30-year interval, 1920-1949, had the significant ($p < 0.05$) value of 0.456. This figure provides evidence that Michigan and Ontario fishermen may exploit common stocks or stocks subject to similar fluctuations.

PRODUCTION OF LAKE TROUT IN THE DISTRICTS OF THE MICHIGAN WATERS OF LAKE SUPERIOR IN 1885, 1891-1908, AND 1929-1949

Data published by Smith and Snell (1891) made possible the following compilation of the 1885 production of lake trout in five of the six statistical districts into which the State of Michigan waters of Lake Superior have been divided (see Fig. 2 for boundaries of the districts):

District	*Production (thousands of pounds)*
S-2	36
S-3	500
S-4	298
S-5	21
S-6	472
Total	1,327

In the Smith and Snell tabulation the Isle Royal fishery (S-1) was combined with that along the Minnesota "North Shore" (excluding Duluth). It can be stated only that the 1885 catch in district S-1 was not large since the production of lake trout in the Isle Royal and North Shore waters combined amounted to only 56,000 pounds. The 1885 total of 1,327,000 pounds which has long been accepted for the State of Michigan waters is accordingly not greatly in error.

In an earlier paper (Hile, 1949) on the lake trout fishery of Lake Huron the records of production in the statistical districts of the United States waters in 1891-1908 were held to " . . . supply a better idea of the relative natural productive capacities of the different areas than is to be had from the recent figures . . . " The same view cannot be maintained toward the corresponding statistics for Lake Superior (Table 3) because of the strong probability that in some areas the extent of fishing operations and hence the production may have been controlled largely by transportation facilities and other factors not related to the productivity of the waters. In district S-1, for example, the output of lake trout was negligible or nil in 1892-1893, 1896, and 1902-1903. It is not to be inferred, however, that lake trout were not available for the catching in those years. Isle Royal has never had more than a scattering of year-round inhabitants. Traditionally most or all of the fishing in the region has been conducted by operators (mostly from Minnesota) who move to the island during the fishing season; the catch customarily is marketed by way of Duluth. It is readily understandable that poor success in preceding seasons, difficulties in arranging for the

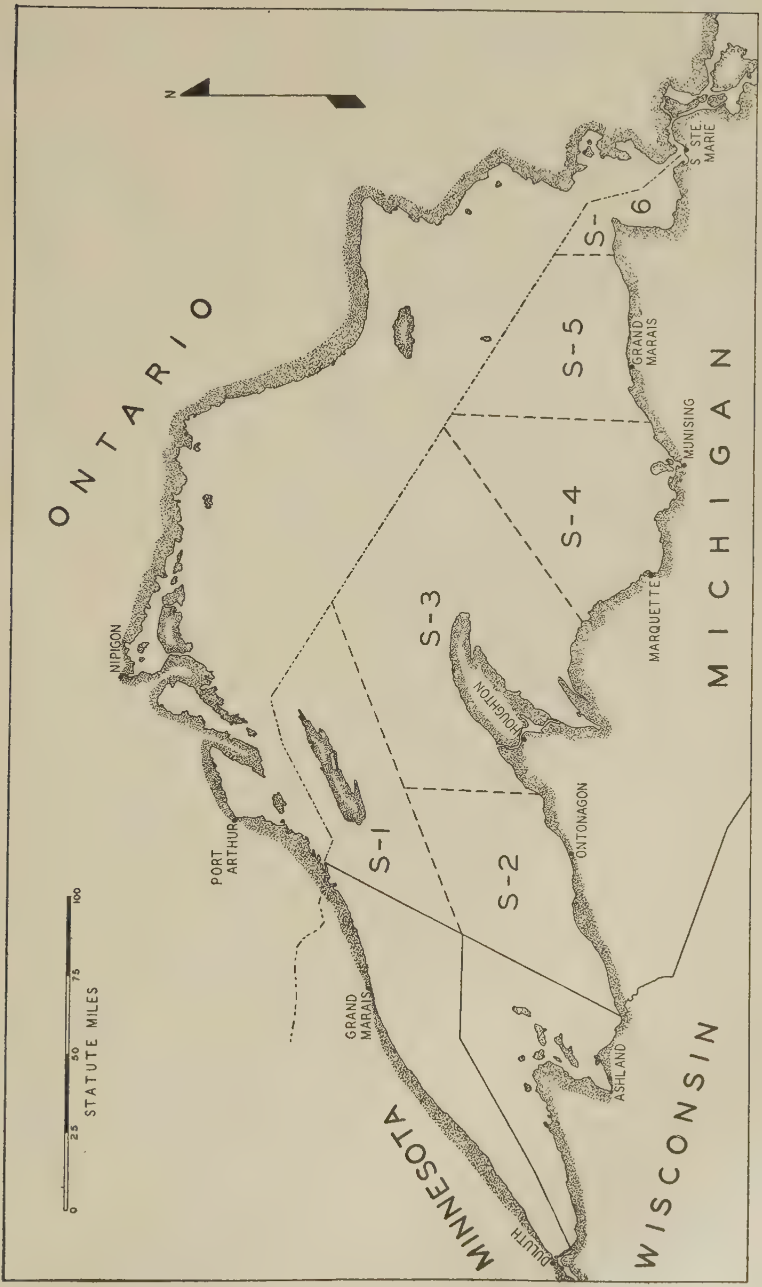
N
ONTARIO
NIPIGON
PORT ARTHUR
GRAND MARAIS
MINNESOTA
DULUTH
WISCONSIN
ASHLAND
ONTONAGON
HOUGHTON
MARQUETTE
MUNISING
GRAND MARAIS
S. STE. MARIE
MICHIGAN
S-1
S-2
S-3
S-4
S-5
S-6
STATUTE MILES
0
25
50
75
100

Figure 2.—Chart of Lake Superior, showing boundaries of the statistical districts, S-1 to S-6, in the State of Michigan waters.

TABLE 3.—*Production (thousands of pounds) of lake trout in the State of Michigan waters of Lake Superior, 1891-1908.*

Year	District						Total
	1	2	3	4	5	6	
1891	855	99	406	267	40	1,062	2,729
1892	....	82	480	414	422	600	1,998
1893	5	64	396	361	511	1,285	2,622
1894	480	71	253	321	615	766	2,506
1895	477	84	315	338	1	1,011	2,226
1896	....	178	388	539	77	1,276	2,459
1897	460	122	393	464	8	1,173	2,620
1898	387	106	369	572	334	906	2,675
1899	355	132	440	682	351	709	2,668
1900	385	131	448	738	262	610	2,575
1901	412	114	457	776	244	1,034	3,039
1902	....	234	538	1,041	295	370	2,478
1903	....	236	770	1,073	748	1,228	4,055
1904	378	179	511	1,106	1,074	1,082	4,330
1905	317	195	513	913	1,010	1,153	4,101
1906	420	225	307	885	807	973	3,617
1907	558	180	284	674	592	628	2,916
1908	300	112	333	630	309	622	2,306
Average......	[1]322	141	422	655	[2]428	916	2,884
Percentage...	11.2	4.9	14.6	22.7	14.8	31.8	....

[1] 13-year average, 445,000 (1892-1893, 1896, and 1902-1903 excluded).
[2] 14-year average, 541,000 (1891 and 1895-1897 excluded).

transportation of the catch to Duluth, or the existence of good fishing nearer home might have led some or even all of these itinerant operators to forego their customary transfer to Isle Royal in some years. The situation may have been similar in district S-5 where production was unimportant in 1891 and 1895-1897. Even today the principal port, Grand Marais, is without railway service. In the earlier years, long before the development of the motor truck, transportation facilities well may have had a major influence on fishing. Even in the remaining districts in which the catch of lake trout did not fall to such low levels, difficulties of marketing may have affected production.

The 1891-1908 statistics for the districts are nevertheless useful in providing minimal estimates of the quantities of lake trout the several regions were capable of producing over a considerable period of years. We know, for example, that S-6, despite its small area yielded lake trout at an average rate of 916,000 pounds and that the take dropped below 600,000 pounds only once (in 1902) and exceeded a million pounds 9 times in 18 years. Similarly, we know that S-4 produced more than a half million pounds (more than a million in 1902-1904) in each of 11 consecutive years and had an average of 655,000 pounds for the 18-year period. In these two and in the remaining four districts as well, the stocks of lake trout might have been able to support a higher production than that recorded in Table 3. Consequently neither the figures on catch nor the data on the percentage contribution to the total for the lake[1] can be accepted as measures of the productive capacities actual or relative, of the different districts. Even these minimal figures on take, however, can be instructive in comparisons with data on the modern yield.

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[1] The term "lake" as employed in this and following sections refers to State of Michigan waters only.

A detailed description of the 1891-1908 fluctuations in the output of lake trout in the several districts would be to little point since we lack information on the variations in the abundance of the species and in the intensity of the fishery. Attention is called only to the similarity of the trends in certain areas. Especially striking is the fact that in four districts (S-2, S-3, S-4, S-5) at least two of the three years of highest output fell within the 4-year period, 1903-1906. The high production in those waters together with much better than average catches in S-6 led to lake totals in 1903-1906 that were all higher than those in any of the other 14 years.

To facilitate comparison between the production statistics for 1891-1908 (Table 3) and 1929-1943, the base period for our modern statistics (Table 4), a summary (Table 5) has been prepared. The differences between the two periods were relatively small in some districts, but others experienced large changes in actual production, in percentage contribution to the total, and in rank among the several regions.

TABLE 4.—*Production (thousands of pounds) of lake trout in the State of Michigan waters of Lake Superior, 1929-1949.*

Year	District						Total	Percentage
	1	2	3	4	5	6		
1929	440	130	431	354	452	117	1,924	93
1930	366	150	417	380	334	73	1,720	83
1931	309	116	541	406	418	170	1,961	95
1932	314	92	457	345	586	177	1,971	96
1933	336	113	442	304	308	202	1,706	83
1934	354	129	555	449	625	381	2,493	121
1935	441	160	564	536	655	240	2,596	126
1936	377	178	539	391	571	263	2,319	113
1937	337	176	517	396	608	258	2,291	111
1938	393	155	538	408	532	158	2,184	106
1939	369	135	460	385	496	88	1,934	94
1940	344	172	450	315	465	96	1,843	89
1941	301	135	467	349	461	157	1,871	91
1942	310	101	568	391	518	134	2,023	98
1943	313	133	647	367	483	147	2,089	101
Average. .	354	138	506	385	501	177	2,062	....
Percentage	17.2	6.7	24.5	18.7	24.3	8.6	....	....
1944	417	184	808	477	601	212	2,700	131
1945	384	216	789	520	450	203	2,562	124
1946	374	192	776	553	441	259	2,594	126
1947	337	171	781	418	361	159	2,226	108
1948	386	185	663	402	373	153	2,161	105
1949	334	170	728	432	387	131	2,181	106

In three districts (S-1, S-3, S-5) the production of lake trout was higher in 1929-1943 than in 1891-1908 (increases of 32,000 to 84,000 pounds). The take declined in the remaining three areas. The decrease was small in S-2 (only 3,000 pounds), large in S-4 (270,000 pounds),

TABLE 5.—*Average production (thousands of pounds), percentage of total for State of Michigan waters of Lake Superior, and rank with respect to productivity for the six statistical districts in 1891-1908 and 1929-1943.*

District	1891—1908			1929—1943			Change from 1891—1908 to 1929—1943		
	Average production	Percentage of total	Rank	Average production	Percentage of total	Rank	Average production	Percentage of total	Rank
1.	322	11.2	5	354	17.2	4	32	6.0	1
2.	141	4.9	6	138	6.7	6	— 3	1.8	0
3.	422	14.6	4	506	24.5	1	84	9.9	3
4.	655	22.7	2	385	18.7	3	—270	—4.0	—1
5.	428	14.8	3	501	24.3	2	73	9.5	1
6.	916	31.8	1	177	8.6	5	—739	—23.2	—4
Total	2,884	. . . .	. . . .	2,062	. . . .	. . . .	—822	. . . .	. . . .

and tremendous in S-6 (739,000 pounds). This drop in S-6, where the 1929-1943 average of 177,000 pounds amounted to only 19.3 percent of the 1891-1908 mean of 916,000 pounds accounted for much of the decrease of 822,000 pounds in the combined districts. The decreases in S-4 and S-6 provide almost conclusive evidence of lowered productivity of the fishery in the two areas.

The differences among the districts in the extent and direction of the change in production were accompanied by some pronounced shifts in the ranking with respect to the contribution to the total output. The greatest change occurred in S-6 which ranked first and contributed 31.8 percent of the 1891-1908 yield but had fallen to fifth position and accounted for only 8.6 percent of the take in 1929-1943. District S-4 also suffered a decrease in the percentage contributed to the total (from 22.7 to 18.7 percent) and a drop in ranking (from second to third). All of the remaining districts experienced increases in the percentage of the total (from 1.8 in S-2 to 9.9 in S-3) and all but S-2 improved their rankings. District S-3 moved from fourth position in 1891-1908 to first in 1929-1943, S-5 from third to second, and S-1 from fifth to fourth. District S-2 ranked sixth in both periods. These changes in percentage contribution resulted in a shift toward the west in the centers of production. Districts S-1, S-2, and S-3 which together contributed only 30.7 percent of the 1891-1908 catch accounted for 48.4 percent of the take in 1929-1943. The percentage for S-4, S-5, and S-6 dropped correspondingly from 69.3 in the former period to 51.6 in the latter.

Despite certain irregularities in the 1929-1949 data and some difference among the districts in actual timing, all areas exhibited the periodic fluctuations mentioned in the comments of the preceding section on production in the State of Michigan waters and in Lake Superior as a whole. These fluctuations were characterized by peaks in the middle 1930's and middle 1940's (Table 6; see also Table 4 and Figs. 3 and 4).

The earlier peak fell in 1935 in four districts, in 1934 in one, and in 1936 in one. The years of the second peak were 1944 in three districts, 1945 in one and 1946 in two. The intervening minimum year was 1939 in one district, 1940 in two, 1941 in two and 1942 in one. The interval between the peaks was 9 years for districts S-1, S-2, S-3, and S-5, 11 years for S-4, and 12 years for S-6.

As would be expected, the production statistics for the combined districts exhibited a similar cyclic trend (Table 6 and right-hand columns of Table 4). From a level of 1,924,000 pounds (93 percent of the 1929-1943 mean) in 1929 the take dropped to 1,720,000 pounds (83 percent) in 1930, increased to 1,971,000 (96 percent) pounds in 1932, declined to 1,706,000 pounds (83 percent) in 1933 and then rose to a peak of 2,596,000 pounds (126 percent) in 1935. Following this maximum the take decreased consistently to a low of 1,843,000 pounds (89 percent) in 1940 and then rose consistently to 2,700,000 pounds (131 percent) in 1944. This second peak was followed by a new, though irregular

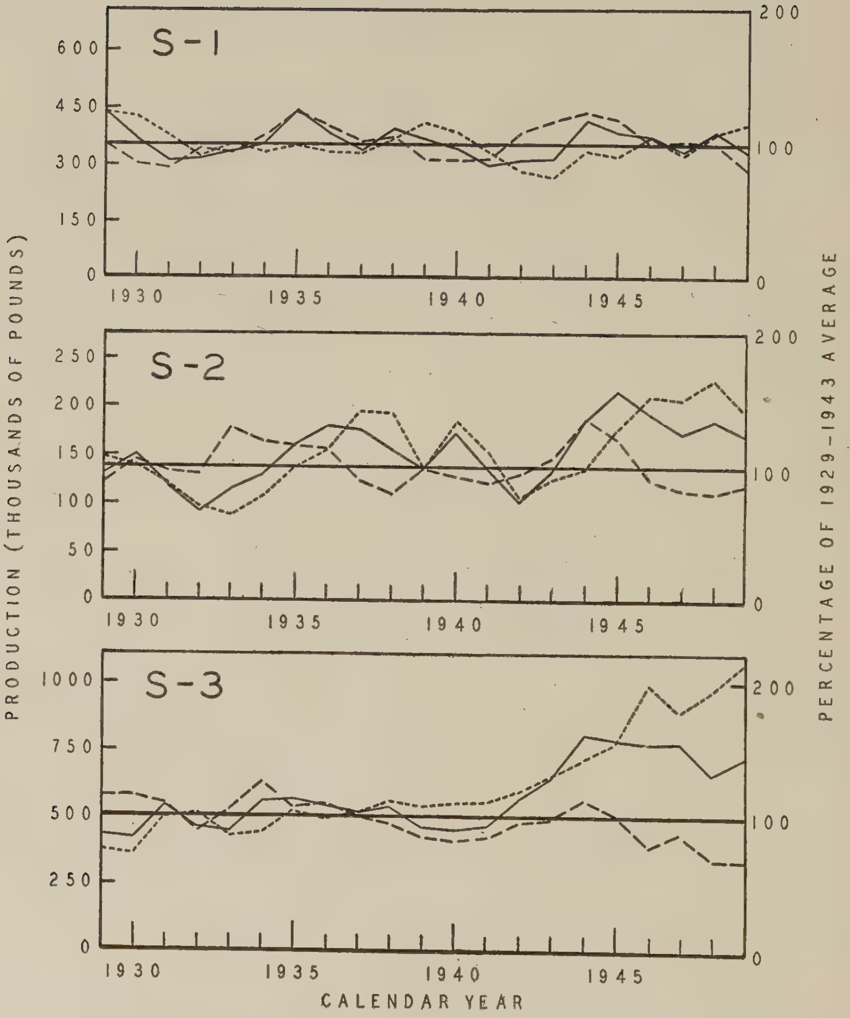

FIGURE 3.—Production (solid line) and index of abundance (long dashes) of lake trout and fishing intensity for the species (short dashes) in districts S-1, S-2, and S-3, 1929-1949, expressed as percentages (scale at right) of the 1929-1943 mean. Production given also in pounds (scale at left).

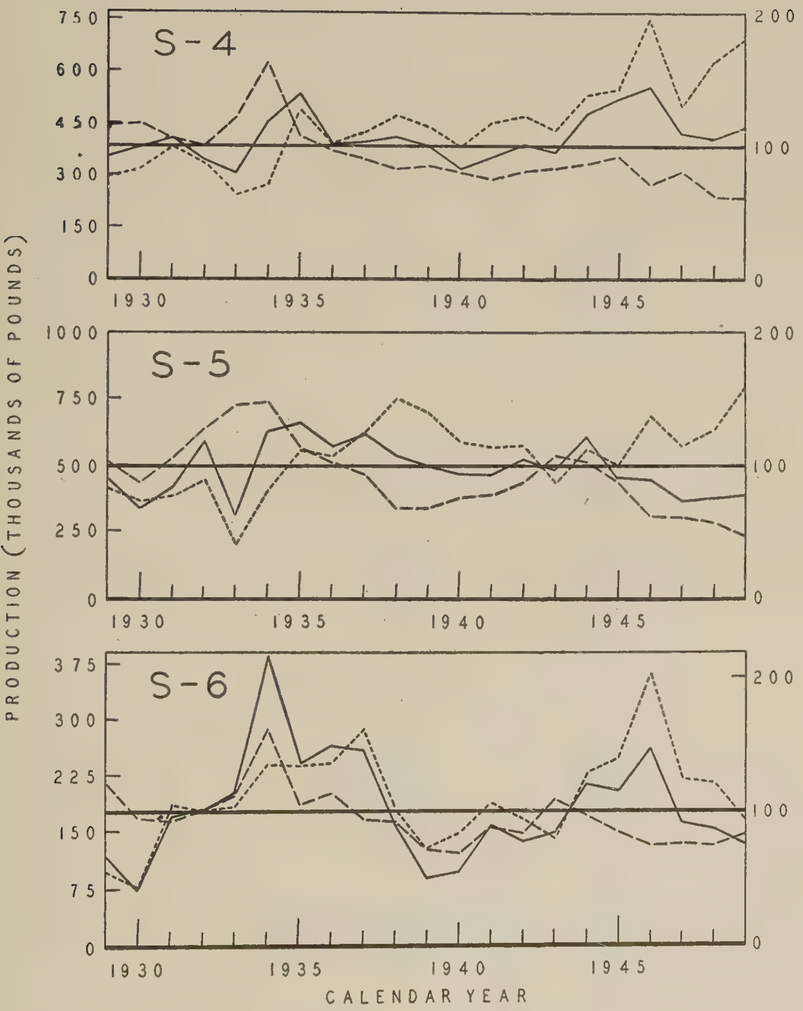

FIGURE 4.—Production (solid line) and index of abundance (long dashes) of lake trout and fishing intensity for the species (short dashes) in districts S-4, S-5, and S-6, 1929-1949, expressed as percentages (scale at right) of the 1929-1943 mean. Production given also in pounds (scale at left).

TABLE 6.—*Peak years and years of the intervening minimum in the cyclic fluctuations of production of lake trout in the State of Michigan waters of Lake Superior, 1929-1949.*

District	First peak			Intervening minimum			Second peak			Interval between peaks (years)
	Year	Production		Year	Production		Year	Production		
		Thousands of pounds	Percentage of average		Thousands of pounds	Percentage of average		Thousands of pounds	Percentage of average	
1..........	1935	441	125	1941	301	85	1944	417	118	9
2..........	1936	178	129	1942	101	73	1945	216	157	9
3..........	1935	564	111	1940	450	89	1944	808	160	9
4..........	1935	536	139	1940	315	82	1946	553	144	11
5..........	1935	655	131	1941	461	92	1944	601	120	9
6..........	1934	381	215	1939	88	50	1946	259	146	12
All.......	1935	2,596	126	1940	1,843	89	1944	2,700	131	9

decline to 2,161,000 pounds (105 percent) in 1948. The slight increase in 1949 (to 2,181,000 pounds or 106 percent) may mark the beginning of a new upswing or may represent merely an irregularity in the downward trend.

ABUNDANCE OF LAKE TROUT IN THE DISTRICTS OF THE MICHIGAN WATERS OF LAKE SUPERIOR, 1929-1949

The estimates of the fluctuations in the abundance or availability of lake trout in the several districts (Table 7; see also Figs. 3 and 4) have been based largely on the records of the catch per unit of effort of large-mesh (4½ inches and greater, extension measure) gill nets (Table 8). During the base period 1929-1943 that gear accounted for 64.5 percent of the total catch of the combined districts.[2] Set-hooks (Table 9) which contributed 30.5 percent of the 1929-1943 take were of less significance but still important. Pound nets (Table 10) produced but 2.1 percent of the 15-year catch and were sufficiently important to be considered in the estimation of abundance in S-3 and S-6 only.

The abundance percentages of Table 7 exhibit a cyclic fluctuation (Table 11) closely similar to that described in the previous section on production. (The only difference of any consequence is the tendency

TABLE 7.—*Abundance of lake trout in the State of Michigan waters of Lake Superior according to statistical district and for the districts combined, 1929-1949.*

[Expressed as percentages of the 1929-1943 mean]

Year	District						Average[1]
	1	2	3	4	5	6	
1929	100	87	114	115	103	120	108
1930	85	105	114	117	87	95	101
1931	82	96	108	105	105	93	100
1932	96	94	88	100	127	100	103
1933	94	128	103	121	145	112	117
1934	106	118	125	162	147	161	137
1935	124	115	106	107	113	104	111
1936	113	113	109	96	102	113	106
1937	102	89	99	90	93	93	95
1938	106	79	94	83	67	92	86
1939	89	98	84	85	67	71	81
1940	88	92	81	80	75	68	80
1941	89	87	83	75	77	87	82
1942	109	94	94	81	86	83	91
1943	117	105	98	83	106	108	102
1944	123	135	111	87	102	96	107
1945	118	120	100	92	86	84	98
1946	100	90	77	71	61	74	77
1947	102	82	86	81	60	75	80
1948	100	80	67	62	56	74	70
1949	81	86	66	60	46	82	65

[1] In the computation of the average the abundance percentage of each district was weight by the percentage of the total 1929-1943 production contributed by that district.

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[2] Statements as to the percentage of the total catch produced by different gears are based on original records not presented here.

TABLE 8.—*Catch (pounds) of lake trout per lift of 10,000 linear feet of large-mesh gill nets (4½ inches and greater, extension measure) in the several districts of the State of Michigan waters of Lake Superior, 1929-1949.*

Year	Catch per lift of 10,000 feet of large-mesh gill nets					
	S-1	S-2	S-3	S-4	S-5	S-6
1929	219	149	201	242	366	208
1930	203	158	197	259	305	231
1931	178	137	188	232	362	225
1932	231	143	149	211	444	243
1933	215	206	169	227	519	326
1934	245	185	196	308	519	353
1935	271	153	162	215	388	289
1936	263	177	178	220	313	257
1937	220	144	143	172	297	219
1938	223	132	123	156	203	228
1939	196	170	117	163	206	143
1940	206	157	115	168	243	190
1941	219	140	125	159	260	209
1942	248	154	150	168	290	217
1943	274	170	150	171	360	255
Average	227	158	158	205	338	240
1944	270	222	166	162	351	218
1945	261	200	154	176	286	208
1946	207	144	112	139	197	217
1947	226	134	129	160	199	221
1948	235	126	101	117	188	183
1949	185	138	102	116	160	198

TABLE 9.—*Catch (pounds) of lake trout per lift of 1,000 set-hooks in the several districts of the State of Michigan waters of Lake Superior, 1929-1949.*

Year	Catch per lift of 1,000 set-hooks					
	S-1	S-2	S-3	S-4	S-5	S-6
1929	687	195	166	285	271	358
1930	480	273	162	251	256	317
1931	559	268	148	222	330	317
1932	557	235	152	239	376	300
1933	593	303	199	370	313	384
1934	648	288	262	448	407	451
1935	874	314	221	272	331	293
1936	672	266	194	217	354	335
1937	709	205	200	246	310	269
1938	771	185	208	230	286	241
1939	587	193	169	238	351	210
1940	530	179	179	191	275	175
1941	490	185	192	178	269	180
1942	697	181	221	196	294	257
1943	652	225	258	210	364	374
Average	634	233	195	253	319	297
1944	938	235	322	293	324	295
1945	810	236	295	310	283	210
1946	848	196	239	213	251	128
1947	704	172	229	234	209	147
1948	581	184	199	215	200	106
1949	517	190	171	195	149	112

TABLE 10.—*Catch (pounds) of lake trout per lift of one pound net in districts S-3 and S-6 of the State of Michigan waters of Lake Superior, 1929-1949.*

Year	Catch per lift of one pound net		Year	Catch per lift of one pound net	
	S-3	S-6		S-3	S-6
1929	60	35	1941	63	14
1930	72	6	1942	50	7
1931	70	18	1943	86	13
1932	38	17			
1933	31	14	Average	56	18
1934	42	37			
1935	47	21	1944	37	18
1936	49	26	1945	45	15
1937	62	20	1946	80	15
1938	54	18	1947	95	3
1939	79	16	1948	32	8
1940	44	7	1949	54	4

for the peaks and the intervening minimum of production to fall a little later than those of abundance and for the first of the two peaks to be the higher in the abundance curves.) The first of the two peaks of abundance occurred in 1934 in four districts, in 1933 in one, and in 1935 in one. The year of the intervening minimum was 1940 in three areas, 1938 in two (the 1938 and 1939 figures were identical in S-5), and 1941 in one. The second peak was reached in 1944 in three districts, in 1943 in two, and in 1945 in one. With the single exception of S-2, the level of abundance attained at the second peak was lower than that of the first. Especially striking was the situation in S-4 where the abundance percentage attained the high figure of 162 in 1934 but failed even to reach the 1924-1943 mean of 100 at the second peak in 1945. The difference between the first and second peaks was large also in S-5 and S-6, was reduced in S-3, and unimportant in S-1. In the four eastern districts the differences between the earlier and later peaks seem to be part of a general downward trend in the level of abundance.

The cyclic character of the fluctuations in availability and the general downward trend are distinctly apparent in the data for the combined

TABLE 11.—*Peak years and years of the intervening minimum in the cyclic fluctuations of abundance of lake trout in the State of Michigan waters of Lake Superior, 1929-1949.*

District	First peak		Intervening minimum		Second peak		Interval between peaks (years)
	Year	Abundance	Year	Abundance	Year	Abundance	
1	1935	124	1940	88	1944	123	9
2	1933	128	1938	79	1944	135	11
3	1934	125	1940	81	1944	111	10
4	1934	162	1941	75	1945	92	11
5	1934	147	1938-39	67	1943	106	9
6	1934	161	1940	68	1943	108	9
All	1934	137	1940	80	1944	107	10

districts (right of Table 7). From a level of 108 in 1929 the abundance percentage declined to 100 in 1931, increased to a maximum of 137 in 1934, decreased to a minimum of 80 in 1940, rose to a new peak of 107 in 1944, and started again on a decline (interrupted by a small increase in 1947) that led to a value of only 65 in 1949—the lowest level in the 21-year interval.

That the fluctuations in the availability of lake trout in the different districts exhibited certain similarities is obvious from the previous comments on cyclic fluctuations. To provide a more precise measure of the extent of these agreements coefficients of correlation (r) between abundance percentages over the 21-year period, 1929-1949, were computed for all possible pairings of the districts (Table 12). The coefficients for all 10 combinations of the mainland districts (S-2 through S-6) were significant and those for the four easterly districts (S-3 through S-6) were extremely high ($p < 0.001$ for all six values). Somewhat lower were the correlations between the fluctuations of abundance in these four easterly districts and those in S-2, the other mainland district, but even of these coefficients two (S-2 and S-3; S-2 and S-5) were significant at the 1-percent level of probability and the remaining two (S-2 and S-4; S-2 and S-6) at the 5-percent level. The availability of lake trout in the Isle Royal region (S-1) seems to have varied independently from that in most mainland waters. Only one of the coefficients, that between the percentages for S-1 and S-2 was significant ($p < 0.05$). The remaining coefficients were all positive but only one of them ($r = 0.372$ for S-1 and S-3) reached a figure corresponding to a 10-percent level of probability.

TABLE 12.—*Coefficients of correlation* (r) *between annual fluctuations in the abundance of lake trout in the statistical districts of the State of Michigan waters of Lake Superior, 1929-1949.*

[Values of r corresponding to probabilities (p) of 0.10, 0.05, 0.01 and 0.001 are 0.369, 0.433, 0.549, and 0.665, respectively]

District	District					
	S-1	S-2	S-3	S-4	S-5	S-6
S-1	....	0.484	0.372	0.094	0.275	0.286
S-2	0.484	....	0.625	0.526	0.663	0.475
S-3	0.372	0.625	....	0.845	0.749	0.769
S-4	0.094	0.526	0.845	....	0.831	0.850
S-5	0.275	0.663	0.749	0.831	....	0.811
S-6	0.286	0.475	0.769	0.850	0.811	....

We are not in position to speculate as to whether the fishermen in the areas exhibiting significantly correlated fluctuations in the abundance of lake trout are drawing on a common stock or whether they are merely exploiting populations in which the factors controlling availability in 1929-1949 were the same or subject to similar annual fluctuations. We need first to obtain definite information on the nature of the factors that control the abundance of lake trout and on the extent of the migrations undertaken by that fish.[3]

INTENSITY OF THE FISHERY FOR LAKE TROUT IN THE DISTRICTS OF THE MICHIGAN WATERS OF LAKE SUPERIOR, 1929-1949

The distinctly cyclic fluctuations that were described in the preceding sections on the production and abundance of lake trout are much less apparent in the data on fishing intensity (Table 13; Figs. 3 and 4). Although a suggestion of periodicity is to be seen in the figures on fishing intensity in several of the districts, the fluctuations could be termed sharply cyclic only in S-6 (distinct peaks in 1937 and 1946 with a minimum in 1939). If the decline in 1949 is interpreted as the beginning of a downward trend from a peak in 1948, the fluctuations in S-2 also can be termed periodic (earlier peak in 1937; minimum in 1942). In some districts (S-3, S-4, S-5) the data suggest the possibility that a tendency toward a cyclic fluctuation may have been obscured by a long-term upward trend that was becoming stronger toward the close of the 21-year period.

TABLE 13.—*Intensity of the fishery for lake trout in the State of Michigan waters of Lake Superior, 1929-1949.*

[The unit corresponds to 1/1500 of the total expected catch for all districts over the 15-year period, 1929-1943]

Year	District						Total
	1	2	3	4	5	6	
1929	20.9	7.1	17.9	14.6	20.9	4.5	85.9
1930	20.4	6.7	17.3	15.4	18.2	3.6	81.6
1931	17.9	5.7	23.8	18.5	19.0	8.5	93.4
1932	15.4	4.6	24.6	16.3	21.9	8.2	91.0
1933	16.9	4.2	20.5	11.9	10.1	8.4	72.0
1934	15.8	5.1	21.2	13.2	20.2	10.9	86.4
1935	16.8	6.6	25.1	23.9	27.6	10.9	110.9
1936	15.9	7.5	23.6	19.2	26.7	11.0	103.9
1937	15.7	9.3	24.8	20.8	31.1	13.1	114.8
1938	17.6	9.2	27.1	23.4	37.4	8.2	122.9
1939	19.7	6.5	25.9	21.6	34.9	5.9	114.5
1940	18.6	8.8	26.4	18.7	29.3	6.8	108.6
1941	15.9	7.4	26.7	22.0	28.2	8.6	108.8
1942	13.5	5.1	28.5	23.0	28.6	7.7	106.4
1943	12.7	6.0	31.4	20.9	21.5	6.4	98.9
Average......	16.9	6.7	24.3	18.9	25.0	8.2	....
1944	16.1	6.5	34.5	26.1	27.9	10.4	121.5
1945	15.4	8.5	37.4	26.8	24.8	11.4	124.3
1946	17.7	10.1	47.9	37.0	34.2	16.5	163.4
1947	15.6	9.9	43.1	24.4	28.5	10.1	131.6
1948	18.3	10.9	47.0	30.8	30.8	9.9	147.7
1949	19.4	9.4	52.2	34.0	39.7	7.5	162.2

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[3] The continuation and expansion of tagging experiments started on a limited scale in October 1950 should yield data on this point. The first 6 recoveries (all made in November and December 1950 and January 1951) from 116 lake trout tagged at Bete Grise Bay on the east shore of the Keweenaw Peninsula near the tip suggest that adult lake trout may undertake extensive migrations. Only two of the six fish were recaptured locally (that is, within a range of 20-30 miles). Two were taken off Munising, Michigan, one off the Gooseberry River in Minnesota waters and one near the Slate Islands in extreme northern Lake Superior (Ontario waters).

TABLE 14.—*Two years of highest and of lowest fishing intensity and comparison of average intensity in 1944-1949 and 1946-1949 with the mean for the base period 1929-1943 in the statistical districts of the State of Michigan waters of Lake Superior.*

District	Years of lowest intensity	Years of highest intensity	Average intensity in period					
			1929—1943		1944—1949		1946—1949	
			Units[1]	Percentage[2]	Units[1]	Percentage[2]	Units[1]	Percentage[2]
1	1943—1942	1929—1930	16.9	100	17.1	101	17.8	105
2	1933—1932	1948—1946	6.7	100	9.2	137	10.1	151
3	1930—1929	1949—1946	24.3	100	43.7	180	47.6	196
4	1933—1934	1946—1949	18.9	100	29.8	158	31.6	167
5	1933—1930	1949—1938	25.0	100	31.0	124	33.3	133
6	1930—1929	1946—1937	8.2	100	11.0	134	11.0	134
All	1933—1930	1946—1949	100.0	....	141.8	....	151.2	....

[1] See caption of Table 13 for definition of unit.
[2] Percentage of 1929—1943 mean for district.

This upward trend in the fishing pressure is without question the most significant feature of the data of Table 13 and Figures 3 and 4. Because the trends in some districts are clouded by random and cyclic fluctuations certain of the data of Table 13 have been summarized in Table 14.

The agreement among the five mainland districts (S-2 to S-6) with respect to years of highest and lowest intensity and the level of fishing pressure in recent years was generally good. In the listing of the two years of lowest fishing intensity, for example, all 10 entries fell within the 6-year period, 1929-1934. Similarly, 8 of the 10 years of highest intensity came within the 4-year interval, 1946-1949 (see left-hand part of Table 14). The districts agreed also in showing a general level of fishing well above the 1929-1943 mean during recent years (see right-hand part of Table 14). Over the 6 years, 1944-1949, the average intensity expressed as a percentage of the 15-year mean ranged from 124 percent in S-5 to 180 percent in S-3. With the exception of S-6 these percentages were even higher in the 4 most recent years for which we have data—from 133 percent in S-5 to 196 percent in S-3.

District S-1 did not share this high level of fishing intensity that characterized the mainland areas. The years of minimum fishing pressure were fairly recent (1943 and 1942) whereas the most intensive fishing occurred in 1929 and 1930. Furthermore, the level of intensity was but little above the 1929-1943 mean in 1944-1949 (101 percent of average) and 1946-1949 (105 percent).

Despite certain erratic and possibly some periodic fluctuations, the fishing intensity for lake trout in the combined districts (right of Table 13) shows distinctly the long-term upward trend described for the mainland waters. Fishing intensity was consistently below the 1929-1943 average during the 6 years 1929-1934. The value of 72.0 in 1933 was the lowest in the 21 years for which we have records. From the 1933 minimum, fishing pressure increased irregularly to a peak of 122.9 in 1938 and then declined to 98.9 in 1943 (the only year since 1934 in which intensity has been below average). The intensity index rose sharply to 121.5 in 1944, increased a little in 1945, and then jumped to the 21-year maximum of 163.4 in 1946. A drop to 131.6 in 1947 was followed by two successive increases that carried the index to 162.2 —only a little short of the 1946 figure—in 1949. The average figure for 1944-1949 (Table 14) was 141.8 and the mean for the 4 most recent years, 1946-1949, was 151.2. In every year after 1944 the fishing intensity exceeded (usually by a wide margin) the maximum recorded for 1929-1944.

RELATIONSHIPS AMONG PRODUCTION, ABUNDANCE, AND FISHING INTENSITY

The relationships among the production and abundance of lake trout and the intensity of the lake trout fishery in the combined districts of the State of Michigan waters of Lake Superior (Table 15; Fig. 5) are in disagreement with situations usually encountered and commonly held to be typical under normal fishing conditions. In this "normal" situation the fluctuations are such that production serves as a reasonably dependable indicator of changes in abundance, and fishing intensity tends to increase with rising abundance and to decrease with declining abundance.

TABLE 15.—*Fluctuations in the production and abundance of lake trout and in the intensity of the lake trout fishery in the State of Michigan waters of Lake Superior.*

[Expressed as percentages of the 1929-1943 mean]

Year	Production	Abundance	Intensity	Year	Production	Abundance	Intensity
1929	93	108	86	1940	89	80	109
1930	83	101	82	1941	91	82	109
1931	95	100	93	1942	98	91	106
1932	96	103	91	1943	101	102	99
1933	83	117	72	1944	131	107	122
1934	121	137	86	1945	124	98	124
1935	126	111	111	1946	126	77	163
1936	113	106	104	1947	108	80	132
1937	111	95	115	1948	105	70	148
1938	106	86	123	1949	106	65	162
1939	94	81	114				

Van Oosten, Hile, and Jobes (1946) held that " . . . there is good reason to believe that under normal conditions (without disruption in the methods or regulations of the fishery), over limited areas, and for short periods of years, large increases or decreases of production may serve as reliable indicators of increases or decreases in the abundance of fish on the grounds." Earlier, Doan (1942) had expressed similar views and had considered it valid to estimate fluctuations in the abund-

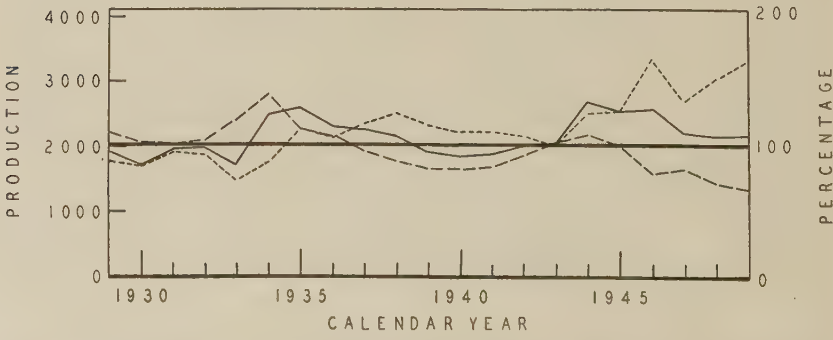

FIGURE 5.—Production (solid line) and index of abundance (long dashes) of lake trout and fishing intensity for the species (short dashes) in the combined districts of the State of Michigan waters of Lake Superior, 1929-1949, expressed as percentages of the 1929-1943 mean (scale at right). Production in thousands of pounds shown by scale at left.

ance of Lake Erie fish from production statistics. In support of his procedure he cited the close agreement between the fluctuations in the catch per net and the total production of walleyes *(Stizostedion v. vitreum)* in four areas of Lakes Huron and Michigan (data from Hile, 1937) and in Lake Erie. More recently, Hile (1949) demonstrated a significant positive correlation between the abundance and production of lake trout in four of six statistical districts and for the combined districts in the United States waters of Lake Huron and Hile, Eschmeyer, and Lunger (1951) observed a similar correlation in five of eight districts and for the combined areas in the State of Michigan waters of Lake Michigan.

In the Michigan waters of Lake Superior the correlation between the production and abundance of lake trout in 1929-1949 was "significant" in S-1 ($r = 0.491$) and "highly significant" in S-6 ($r = 0.608$).[4] The values of the coefficient for the remaining districts and for all areas combined were: S-2, 0.042; S-3, —0.259; S-4, —0.060; S-5, 0.370; all six districts, 0.143. On the whole, therefore, production was highly unreliable as an indicator of changes in the abundance of lake trout in Lake Superior.

The observed usefulness of production statistics as indicators (but not necessarily as measures) of changes of abundance in so many situations hinges on a general tendency for fishing intensity and the abundance of fish to vary independently or to be correlated positively. A description of the relationship between fishing intensity and abundance held by Van Oosten, Hile, and Jobes (1946) to represent normal conditions was given in their comments on the statistics of the whitefish fishery of the State of Michigan waters of Lake Michigan.

> . . . fishing intensity and yield were above average in a large majority of the years in which the abundance of whitefish was above average, and, conversely, fishing intensity and production were below average in the majority of the years in which the abundance of whitefish was below average. There was a tendency also for the percentages of fishing intensity and catch to be greater than the abundance percentages when abundance was above average and less than the abundance percentages when abundance was below average. The curves of fishing intensity tended to lie outside (with reference to the average) the curves of abundance, and the curves of production tended to fall outside both the curves of abundance and fishing intensity.

The coefficient of correlation between the indices of abundance of whitefish and the intensity of the fishing for that species in the State of Michigan waters of Lake Michigan in 1929-1939 was 0.70.

With the Lake Superior lake trout, contrary to the usual relationship just described, the abundance of lake trout and fishing intensity were correlated negatively as the following coefficients of correlation prove.

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[4] With 19 degrees of freedom the absolute values of r corresponding to the 5- and 1-percent levels of probability are 0.433 and 0.549 respectively.

District	r
S-1	—0.590
S-2	—0.568
S-3	—0.728
S-4	—0.768
S-5	—0.804
S-6	—0.025
Combined districts	—0.760

Of the coefficients listed above only the one for S-6 was too small to be considered significant; the values for S-1 and S-2 were beyond the 1-percent level of probability ($r = \pm 0.549$ at $p = 0.01$) and those for S-3, S-4, and S-5 and for the combined districts were beyond the 0.1-percent value ($r = \pm 0.665$ at $p = 0.001$). Especially striking in the data on abundance and fishing intensity is the disagreement in the long-term trends. Despite certain irregularities and a strong indication of periodicity, the trend of abundance of lake trout in 1929-1949 was distinctly downward, and during the same period the trend of fishing pressure was just as definitely upward. This difference of trends led to a strong divergence of the curves of abundance and fishing intensity in the years following 1943.

The sharp rise in the intensity of the fishery for lake trout during recent years in the face of the rapidly declining abundance of the species was made possible first by exceptionally favorable market conditions and second by the existence in Lake Superior of a base-period (1929-1943) average return per unit of effort so high that profitable operations still could be carried on at a *relatively* low level of abundance.

TABLE 16.—*Production of lake trout (thousands of pounds) in Lake Michigan and in the United States waters of Lakes Huron and Superior and percentage distribution of the combined catch among the three lakes 1935-1949.*

Year	Lake Huron		Lake Michigan		Lake Superior		Total production
	Production	Percentage	Production	Percentage	Production	Percentage	
1935	1,743	17.3	4,873	48.3	3,476	34.4	10,092
1936	1,400	14.9	4,763	50.7	3,233	34.4	9,396
1937	1,340	14.2	4,988	53.0	3,085	32.8	9,413
1938	1,270	13.6	4,906	52.5	3,167	33.9	9.343
1939	1,372	14.0	5,660	57.9	2,744	28.1	9,776
1940	940	9.5	6,266	63.4	2,677	27.1	9,882
1941	892	8.5	6,788	64.4	2,854	27.1	10,534
1942	728	7.2	6,484	63.7	2,959	29.1	10,171
1943	459	4.4	6,860	66.2	3,053	29.4	10,372
1944	363	3.4	6,498	61.3	3,740	35.3	10,600
1945	173	1.9	5,437	60.6	3,369	37.5	8,979
1946	38	0.5	3,974	53.3	3,444	46.2	7,456
1947	12	0.2	2,425	44.9	2,964	54.9	5,402
1948	4	0.1	1,197	28.8	2,954	71.1	4,155
1949	1	0.0	342	10.4	2,966	89.6	3,309

The collapse of the lake trout fishery first in Lake Huron and later in Lake Michigan gave Lake Superior fishermen an increasing share in and finally almost a monopoly on the domestic production (Table 16). In 1935, the last year in which the Lake Huron catch exceeded the modern average (Hile, 1949), the percentage distribution of the combined take in the upper lakes[5] was: Lake Huron, 17.3; Lake Michigan, 48.3; Lake Superior, 34.4. In the 9-year period 1935-1943 the percentage of the three-lake total produced in Lake Superior fell within the narrow range 27.1-34.4. An upward trend in the percentage for Lake Superior started in 1942, carried past the 50-percent level in 1947 and reached the high figure of 89.6 percent in 1949. The increase in the relative contribution of Lake Superior was accompanied by a downward trend in the combined catch of lake trout in the upper lakes. During the years 1935-1944 the output varied between 9,343,000 pounds and 10,600,000 pounds, but in 1945 it started a rapid decline that had reached 3,309,000 pounds in 1949. This decrease in the supply placed the Lake Superior fishermen in a highly advantageous position. Demand was brisk, prices were good, and the danger of glutting the market was insignificant.

Despite the economic advantages enjoyed by Lake Superior fishermen, the question still exists as to how fishing intensity could increase in recent years when abundance was declining so rapidly. Even with the best of market conditions, there are limits of availability below which profitable operations are impossible. In earlier accounts of the collapse of the lake trout fishery in Lake Huron (Hile, 1949) and Lake Michigan (Hile, Eschmeyer, and Lunger, 1951) the 50-percent level of production was taken as the "critical point" in the decline but the 70-percent level was selected for abundance because " . . . the fishery had all but disappeared by the time that level of abundance [50 percent] was reached . . . " (Hile, 1949). In Lake Superior, however, the lake trout fishery was far from disappearing in 1948 and 1949 when the abundance percentages for the combined districts were 70 and 65 percent respectively. On the contrary, fishing pressure was high (148 and 162 percent of average) and production was good (105 and 106 percent) in both years. The explanation of continued high fishing intensity and production in years of low abundance is to be found in the comparison of the 1929-1943 average catch per unit of fishing effort in the several statistical districts of the State of Michigan waters of Lakes Huron, Michigan, and Superior (Table 17). These figures are the absolute standards from which the percentage fluctuations of abundance in the different areas were computed. Although a detailed comparison of the average catch per lift for each Lake Superior district with the average for the corresponding gear in each district of Lake Huron and Lake Michigan will reveal certain exceptions, it can be stated, nevertheless, that the standards were generally the higher in Lake Superior. In other words better fishing (in terms of catch per unit of effort) is required in most Lake Superior districts to give an

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[5] The production of lake trout has been nil in recent years in Lake Erie and has been unimportant in Lake Ontario—consistently below 20,000 pounds and sometimes less than 10,000 pounds.

TABLE 17.—*Average catch of lake trout (pounds) per lift of 10,000 linear feet of large-mesh (4½ inches and greater) gill nets and per lift of 1,000 set-hooks in the statistical districts of the State of Michigan waters of Lakes Huron, Michigan, and Superior, 1929-1943.*

Lake Huron			Lake Michigan			Lake Superior		
District	Gill nets	Set-hooks	District	Gill nets	Set-hooks	District	Gill nets	Set-hooks
H-1	113	207	M-1	102	184	S-1	227	634
H-2	196	215	M-2	151	190	S-2	158	233
H-3	154	189	M-3	131	143	S-3	158	195
H-4	161	109	M-4	105	128	S-4	205	253
H-5	148	184	M-5	101	242	S-5	338	319
H-6	75	191	M-6	109	121	S-6	240	297
			M-7	179	164			
			M-8	160	174			
Average	141	182	Average	130	168	Average	221	322

estimate of normal abundance (100 percent) than is necessary in most areas of Lakes Huron and Michigan. Furthermore, an abundance of only 65 or 70 percent in Lake Superior corresponds to a success of fishing that would be considered normal or better in most of Lake Huron or Lake Michigan.

Comforting as it may be to know that the quality of lake trout fishing in the Michigan waters of Lake Superior was still good in 1948 and 1949 in spite of the relatively low availability of fish, the general situation must be recognized as dangerous. The trends as shown in Table 15 and Figure 5 cannot continue much longer. Still further decreases in the abundance of lake trout inevitably must reduce the catch per unit of effort to the level at which operations are no longer profitable. When that point is reached, fishing intensity and production must be expected to drop abruptly. Only a reversal of the present trend in the abundance of lake trout can save the fishery from disaster.

The appraisal of the status of the stocks of lake trout is made even more discouraging by the knowledge that our estimates of abundance in the past few years have been too high and our estimates of fishing intensity too low. Three factors have contributed to our errors: the gradual replacement of cotton and linen gill nets by the more efficient nylon nets[6]; the extension of operations to deeper water as the result of the development of floats capable of withstanding pressures up to 120 fathoms and deeper; the installation on numerous boats of sonic depth-finders which made possible the more accurate placement of the nets at the desired depth and also the location of new grounds in areas formerly believed to be uniformly too deep for fishing. As a result of these improvements gill-netters in recent years have been taking greater quantities of fish per unit of fishing effort than would have been possible at the same level of abundance with the gear and equipment of much of the 1929-1943 base period. At the same time the actual pressure on the population has been greater than the mere length of gill nets (the principal gear) lifted would indicate.

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[6] We are without good information on the relative efficiency of nylon and cotton or linen gill nets. The advantage of the nylon webbing doubtless varies with the species, the method of hanging the net, and possibly with other factors. The only quantitative data on the efficiency of nylon nets in the lake trout fishery of Lake Superior are from observations by Mr. Leo F. Erkkila, Fishery Research Biologist, in charge of the Service's field station at Marquette, Michigan, on a small number of lifts from that port in which both nylon and linen nets were fished. According to Mr. Erkkila's counts the nylon nets in these gangs took 2½ times as many fish as the linen nets. The effect of the introduction of nylon netting on the data given in this paper is probably small and limited to 1949. According to information supplied by fishermen, nylon netting was not fished before 1949 and its use was limited in that year. At Marquette nylon nets appear to have been fished for the first time in 1950.

We should be in much better position to speculate as to the future of the lake trout fishery in Lake Superior if we knew the cause of the present downward trend of abundance. The upward trend of fishing pressure and the high negative correlation between abundance and fishing intensity in most districts and in the combined areas invite the belief that the two may be related causally — that rising fishing pressure has brought about a decrease of abundance and that the fishermen in the face of this reduced availability have intensified their efforts in order to keep production at a good level. If so, a continuation of present trends until fishing becomes unprofitable is to be anticipated. On the other hand, it is possible that the rising fishing pressure has been merely the result of a natural decline in abundance but has not contributed materially to it. In this event, we can hope for a natural upturn of abundance which would relieve the precarious status of the fishery. Regardless of the causes that led to the present situation, the fact remains that the lake trout stocks of the State of Michigan waters of Lake Superior are fast nearing a dangerously low level and are in poor condition to withstand the impending ravages of a growing population of sea lampreys.

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Part II

Business Sessions

AMERICAN FISHERIES SOCIETY

EIGHTIETH ANNUAL MEETING

The eightieth annual meeting of the Society was opened in the Peabody Hotel, Memphis, Tennessee, at 9:30 a.m., Monday, September 11, 1950. The agenda were as follows:

Monday, September 11

Morning: Address of the President; roll call of members; action on nominations for membership; introduction of noteworthy guests and visitors; appointment of sessional committees; reports of officers; chairmen of regional divisions, standing committees and *ad hoc* committees.

Afternoon: Presentation and discussion of papers.

Tuesday, September 12

Morning and Afternoon: Presentation and discussion of papers.

Evening: Reports of sessional committees; election of officers, and of committee members subject to election; installation of the new President; concluding business.

Wednesday, September 13

Morning and Afternoon: Joint field trip with the International Association of Game, Fish and Conservation Commissioners to Pickwick Dam and Park, under the auspices of the Tennessee Game and Fish Commission.

Evening: Annual Banquet — Main Ballroom.

OPENING REMARKS OF THE PRESIDENT

MILTON C. JAMES

Upon induction into office at Winnipeg a year ago, I likened the President of the Society to an insect which indulges in a brief flight, makes due arrangements for the perpetuation of the species, and subsides gracefully into oblivion. I promised to honor this pattern which calls for an opening report to the Society by the President. Of the reports to follow the one which will be most significant and satisfactory to the members is that of the Secretary-Treasurer, but I do not want to steal any of the limelight from George Sprecher by drawing upon it at this time. I do believe that congratulations to the Secretary-Treasurer and to the other officers, particularly the chairman and members of the Membership Committee, are very much in order.

One development of outstanding interest during the past year is the passage of federal legislation which has been endorsed by the Society for at least 10 years, to my knowledge. This is the Dingell-Johnson, or Federal Aid to Fisheries, Bill. It is probably no exaggeration to say that this piece of legislation is the most significant step toward actual accomplishment of the objectives and aims of the Society that has occurred within the present generation. It means that fact-finding can be undertaken on a comprehensive scale, and that concurrently with, or subsequent to, the development of the necessary facts, management practices can be instituted. What more can any fishery biologist or technician ask for? Probably the funds which are now in sight for this program may turn out to be inadequate for a full-scale job, but the start is made, and it may be all for the good that for the first several years we will have to feel our way rather slowly. It is expected that there will be further comment upon this legislation from the appropriate Standing Committee, and discussions of the Dingell-Johnson program in the hotel lobbies and rooms are bound to be active and interesting. I will, therefore, refrain from further comment upon the matter at this time. One word of caution deserves utterance: the times are such that federal financial commitment may be revised drastically downward so far as desirable peacetime functions are concerned.

Anyone who has the privilege of serving as President of the American Fisheries Society cannot help but develop certain impressions of the organization which he may not have got while he was serving in the ranks. It is quite forcibly brought to one's attention that there are aspects of the Society which are not confined to questions of finance, membership, business management, or the various other subjects which will be brought to you in the reports of the other officers and chairmen.

The aspects to which I refer are those concerned with the role of the Society in the present scheme of things biological and technical, in the arena of fisheries conservation and management.

The Society has traditionally been a forum for the presentation of facts and information. The published transactions and the discussions which are conducted at the annual meetings have resulted in a virtual encyclopedia of specialized data and knowledge. The Society has served admirably an important and useful purpose in sponsoring this authoritative compendium over the past years. An encyclopedia is not an end in itself, however, and it has been borne home to me more and more vividly that the publication of papers and reports is not the sole and desirable justification for the existence of the Society. A year ago, President Seth Gordon called your attention to the fact that there was before the Society a broad policy question, involving the organization of the administrative set-up for conservation of fishery and wildlife resources in the United States. Something of a similar nature has been presented to us in the past year in the form of an invitation from the President's Water Resources Policy Commission to offer recommendations and suggestions as to a broad water-use policy for the United States. Both of these subjects are typical of generalized problems or proposals upon which the members of the Society, individually, are highly qualified to speak. Individual views, however, rarely attain enough prominence in the consideration of national questions to have much weight, whereas the views of the Society can acquire the greatest significance.

I realize the difficulties which face us in attempting to formulate views and attitudes upon these extremely broad questions. The problems may affect either the United States or Canada alone, and the members from either side of the line feel reluctant to inject themselves into the internal problems of their neighbor country. The Society now has no practical means of polling the membership to prepare a statement of broad policy views, or securing the approval of such a statement when and if it is drafted by the officers.

With particular reference to the request of the chairman of the Water Resources Policy Commission, a small task force made up of members of the Society has drafted a statement which has been handed to the Executive Committee with the hope that it may be approved and forwarded for consideration. Action has been taken in this way because of a time limit for the submission of comments. It would have been impossible to have appointed a committee at this meeting and expected it to prepare a policy statement which could be circulated for review and forwarded to the President's commission in time to receive any consideration whatever. Your officers have not committed the Society to anything radical or extreme, but have, however, put down in coherent form the principles which seem to have been formulated within the Society over the past years.

Possibly I have spent an undue amount of time in discussing this particular matter, but I have done so in the belief that the American Fisheries Society will be more and more called upon to make up its corporate mind with respect to trends and policies of conservation management, and to make its conclusions known. It will not be enough to refer administrators to the published transactions and invite them to use the facts presented therein, in the formulation of their own policies.

ELECTION OF HONORARY MEMBERS

Under the provisions of Article II, Section 2, of the Constitution, the following members, active in the Society during the past 50 years, were unanimously elected as Honorary Members:

Ward T. Bower

Colburn C. Wood

Mr. Bower and Mr. Wood were nominated for this distinction by the following: C. F. Culler, Seth Gordon, W. J. K. Harkness, Albert S. Hazzard, Elmer Higgins, Joe Hogan, Russell P. Hunter, Milton C. James, E. L. Wickliff and A. H. Wiebe.

APPOINTMENT OF SESSIONAL COMMITTEES

Time and Place

Raymond E. Johnson, Minnesota, *Chairman*
Coit M. Coker, Maryland
Joe Hogan, Arkansas
Elwood A. Seaman, West Virginia
Bruno von Limbach, District of Columbia

Auditing

Andrew L. Pritchard, Ontario, *Chairman*
George W. Davis, Vermont
Richard T. Whiteleather, District of Columbia

Resolutions

Fred A. Westerman, Michigan, *Chairman*
Kenneth D. Carlander, Iowa
John F. Dequine, Florida
Lee S. Roach, Ohio
Roy K. Wood, Georgia

Nominating

C. F. Culler, Minnesota, *Chairman*
A. D. Aldrich, Oklahoma
H. H. MacKay, Ontario
E. F. Swift, Wisconsin
A. C. Taft, California

Publicity

Clinton L. Baker, Tennessee, *Chairman*
Robert O. Beatty, Illinois
John W. Jared, Tennessee

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

George E. Sprecher

The American Fisheries Society has emerged from its eightieth year of existence in an excellent condition. There are now 939 active members in good standing, 43 life members, 19 sustaining members, 55 library members, 35 official members, 42 patrons, and 14 honorary members. This represents an increase over last year of 44 active, 2 sustaining, 7 library, and 2 official members. It also represents a reduction of 2 life members who have passed away during the year. Actually, we have accepted 247 new members but have lost 148 through resignation, non-payment of dues, or death.

Under the new Constitution and By-Laws of the Society any member who fails to pay his dues for a period of more than 1 year and after proper notice from the Secretary is removed from the membership list. These figures, therefore, are quite up-to-date and represent the true working membership of the Society.

The membership committee has done excellent work in recruiting members from the ranks of fishery workers throughout America. Through the efforts of this committee all members who have resigned or who have been dropped for non-payment of dues have been replaced by new members. Only members in good standing have been sent copies of the Transactions. The Librarian has done outstanding work in distributing copies of this publication to schools and to new members of the Society.

Since the last annual meeting of the Society, Volumes 77, 78, and 79 have been distributed to members. For the first time in many years the publication of the Transactions is up-to-date. Three general letters were sent to members during the year. The letter of November 23, 1949, informed members of the highlights of the Winnipeg meeting and also the plans of the various officers and committee chairmen for the coming year. On April 14, 1950, a letter was sent to all members advising them of the 80th Annual Meeting and calling for papers for that meeting. A final notice of the meeting was sent to members on July 1, 1950.

Financial Report

The Society has now recovered from the serious financial situation which prevailed 2 years ago. Before presenting the detailed report, I would like to summarize our financial condition.

The Society's income from all sources except investments and life memberships during the fiscal year was $8,027.98. Our disbursements were $5,439.70. A liability of $3,375.44 to cover payment of Volume 78 was outstanding at the end of the fiscal year. Also, the publication of Volume 79 is chargeable to the income of the 1949-50 fiscal year. The cost of this volume is approximately $4,000. Therefore, the net worth of the Society as of June 30, 1950, with all expenses and transactions to date considered, is approximately $4,005.26. This amount consists of securities valued at $2,277.82 and the balance in cash.

Our financial picture is now quite clear. We have on hand as of June 30, 1950, in cash and securities with all obligations taken care of, $4,005.26. Our expected annual income is $8,500; our expected annual expense is $6,125; and our expected annual surplus is $2,375.

I am pleased to report that we have taken in over $4,852 since July 1, 1950. This indicates a sincere effort on the part of the members of the Society to keep our financial affairs in good order.

There are many factors which we cannot consider in making our plans for the future. A war could certainly reduce the membership and the income of the Society. On the other hand, a flood of new members could greatly increase our receipts. There are other factors which also affect the long-range trend of the Society. I do not like to destroy the rosy financial picture I have just given you but in my position as Secretary of the Society I have been able to observe certain trends before they come to the attention of other members of the Society. It has often been said that every organization contains the seeds of its own destruction. This can be true of the American Fisheries Society. Ex-president Seth Gordon and President M. C. James have repeatedly warned this Society that its future depends on its appeal to every branch of the fisheries and not to any one group or segment of fishery workers. In my opinion, it is highly important that the officers and committee members put every effort into the promotion of the Society as a whole. If this is not done, there is no question in my mind but that the number of members of the Society will decline and as a consequence the financial picture will again deteriorate.

I have only one recommendation to make at this time. The finances of the Society appear to be in such condition that a reduction in dues may be in order for consideration at the 1951 meeting. I suggest that the executive committee give this matter consideration during the coming year and if deemed advisable, submit such a proposal next year.

The detailed financial report is as follows:

July 1, 1949—June 30, 1950

General Fund

Balance on hand, July 1, 1949			$1,846.64

Receipts:

Annual Dues			
Individuals			
For the year	1941-42	$ 3.00	
	1942-43	3.00	
	1943-44	3.00	
	1944-45	3.00	
	1945-46	3.00	
	1946-47	15.00	
	1947-48	102.00	
	1948-49	171.00	
	1949-50	3,333.39	
	1950-51	72.78	
	1951-52	4.50	$3,713.67
State Memberships			
For the year	1948-49	20.00	
	1949-50	1,360.00	
	1950-51	80.00	1,460.00
Library Memberships			
For the year	1945-46	2.00	
	1946-47	2.00	
	1947-48	2.00	
	1948-49	6.00	
	1949-50	172.00	
	1950-51	8.00	192.00
Club Memberships			
For the year	1946-47	5.00	
	1947-48	5.00	
	1948-49	5.00	
	1949-50	140.00	155.00
Sale of Transactions and Special Publication			$2,500.56
Sale of Index			6.75
Total Receipts			$8,027.98
Total Receipts minus July 1 Balance			$6,181.34

Disbursements:

Printing of Transactions	$3,867.84
Other Printing	437.93
Clerical Services	60.80
Postage	203.80
Rental of Meeting Room	50.00
Editing	136.28
Stationery and Supplies	76.67
Fire Insurance	28.92
Reporting Service	300.00

Freight Charges	102.96
Indexing Service (Volume 78)	90.00
Fidelity Bond	18.75
Travel Expense:	
G. E. Sprecher	58.45
Miscellaneous	7.30
Total Disbursements	$5,439.70
Total Receipts minus July 1 Balance, General Fund	$6,181.34
Total Disbursements	5,439.70
Balance, General Fund, June 30	$ 741.64
Transfer from Permanent Fund, June 30, 1950	5,500.00
Balance, General Fund, June 30	$6,241.64

PERMANENT FUND

Balance on hand, July 1		$8,138.16

Receipts:

Individual Life Memberships	$ 204.50	
Dividend Income		
Commonwealth and Southern Preferred Stock	30.00	
Consumers Power Company	42.00	
Central Illinois Light Company	9.90	
Mortgage Certificates		
Principal Distribution	87.50	
Income Distribution	9.18	
Sale of Matured Government Savings Bond	1,000.00	
Total Receipts		$1,383.08
Total		$9,521.24

Disbursements:

Refund of Life Membership	$ 50.00	
Purchase of Government Savings Bonds ($1,000 and $500 Maturity Value)	1,110.00	$1,160.00
Balance, June 30, Permanent Fund		$8,361.24
Transfer to General Fund, June 30, 1950		5,500.00
Balance, June 30, Permanent Fund		$2,861.24

RECAPITULATION

Balance, June 30, General Fund	$6,241.64
Balance, June 30, Permanent Fund	2,861.24
Balance, June 30, both funds	$9,102.88

SECURITIES HELD, JUNE 30, 1950

(1) New York Title and Mortgage Company, Series F-1 Certificate No. 10811	Paid in full
(2) Title Guarantee and Trust Company Certificate No. 103553	$ 40.00

(3)	Title Guarantee and Trust Company Certificate No. B-71070	40.00
(4)	U. S. Government Savings Bond No. D682395F	370.00
(5)	U. S. Government Savings Bond No. M1610061F	740.00
(6)	Consumers Power Company No. G-6085 28 shares at 31⅝	885.50
(7)	Central Illinois Light Company No. 131752 6 shares at 33½	202.32
	Total	$2,277.82

PROPOSED BUDGET

The proposed budget for 1950-51 fiscal year is as follows:

GENERAL FUND

Balance on Hand July 1, 1950		$6,241.64
Estimated Receipts		
939 Active Members at $4.50	$4,225.50	
35 Official Members at $40.00	1,400.00	
19 Sustaining Members at $10.00	190.00	
55 Library Members at $4.00	220.00	
Sale of Publications	2,500.00	
Total Estimated Receipts		8,535.50
Net Estimated Income		$14,777.14
Estimated Disbursements		
Printing—Volume 78	$3,375.44	
Printing—Volume 79	4,000.00	
Printing—Volume 80	4,000.00	
Other Printing	450.00	
Clerical Services	75.00	
Postage	250.00	
Editing	300.00	
Stationery and Supplies	100.00	
Fire Insurance	30.00	
Reporting Service	300.00	
Freight Charges	100.00	
Travel Expense	200.00	
Fidelity Bond	18.75	
Indexing—Volume 80	90.00	
Western Division Meeting	50.00	
Miscellaneous Expense	160.81	
Total Estimated Expense		$13,500.00
Estimated Net Balance, General Fund, June 30, 1951		$ 1,277.14

REPORT OF THE LIBRARIAN

William C. Beckman

The library of the Society was transferred from Ann Arbor, Michigan, to Fort Collins, Colorado, in October, 1949. The Colorado A. and M. College had shelves constructed to house the volumes and provided additional storage space for the overflow. Thanks are due the Michigan Conservation Department, and the Michigan Institute for Fisheries Research, for providing space for the library while it was in Ann Arbor, and for the time of their staff members spent in packing the library and shipping it to Fort Collins.

Since my last report to the Society, three volumes of the Transactions have been published and the overrun sent to the Librarian. We are now up to date in publication and have a good supply of recent volumes on hand.

During the past year the supply of three volumes was exhausted: 1917, 1922, and 1943. Several other volumes are getting low in numbers: 1911 (1), 1921 (4), 1944 (3). From August 1, 1949, to August 17, 1950, 1,000 volumes of the Transactions and Indexes were sold. In addition, 459 copies of Special Publication No. 1 also were sold.

On August 17, 1950, an inventory was taken, at which time 3,258 volumes of the Transactions were on hand, together with 128 paper bound and 492 cloth bound Indexes, and 1,476 copies of Special Publication No. 1.

In October, 1949, Mr. Ward T. Bower wrote Mr. Sprecher that he had located several back volumes of the Transactions which he sent to me. As the Society has complete sets of the Transactions, it was believed the best plan to dispose of these volumes through sales. Therefore I wrote to several libraries which I knew were looking for these particular issues and disposed of most of them in this manner.

Monies received from the sale of the volumes are turned over to the Secretary-Treasurer each month, together with a list of names of the purchasers and the volumes purchased.

I should also like to announce that I have begun work on the Cumulative Index to the Transactions, 1929-1949. It is hoped that this volume will be ready for distribution by this time next year.

Available Volumes of the Transactions of the American Fisheries Society as of August 17, 1950

At $1.00 per volume

1906	50
1907	53
1908	61
1909	33
1910	21
1911	1
1912	68
1913	99
1919	68
1920	49
1921	4
1924	94
1926	176
1926	37
1927	62
1928	41
1929	52

At $3.00 per volume

1930	19	1932	25	1944	5	1945	121
1931	70	1942	51				

At $4.00 per volume

1946	284	1947	840	1948	874	1940	[illegible]

Index 1872-1928

Paper bound—$1.00	128	Cloth bound—$1.50	492

Special Publication No. 1—1,476 copies—25 cents each

REPORT OF THE CHAIRMAN OF THE WESTERN DIVISION

James Y. Simpson[1]

The Western Division of the American Fisheries Society held a meeting jointly with the Western Association of Fish and Game Commissioners in Portland, Oregon, on August 13-15, 1950. Attendance was gratifying: between 50 and 60 members of our Society were present at each afternoon session. The meeting was characterized by good papers and lively discussion on problems of regional interest. Several new members were gained for the Society.

A single resolution was adopted. It is being submitted for consideration by the Resolutions Committee of the parent body.

Officers of the Western Division are: James Y. Simpson, Idaho, Chairman; A. W. Yoder, Arizona, Vice-Chairman; and Fred Thompson, New Mexico, Secretary.

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[1] This report was presented informally by Mr. Fred Thompson, Secretary of the Western Division, in the absence of Mr. Simpson.

REPORTS OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS

Stillman Wright

The past year has been one of great activity and development in international relations pertaining to the fisheries. Although few developments reached full maturity during this period, marked progress was made on projects initiated long ago, and we may expect significant results from them in the coming years.

International Fishery Agreements

As indicated in the 1949 report of the Committee, there is a growing awareness of the desirability of international cooperation in the study and management of fishery resources of interest to more than one country. The successful results achieved by the use of this approach in meeting many international fishery problems in the past have done a great deal to stimulate the use of international agreements in attempts to solve recent problems in this field. With regard to the agreements noted in last year's report, the following progress can be reported:

The International Convention for the Northwest Atlantic Fisheries, which was concluded at Washington on February 8, 1949, entered into force on July 3, 1950, with the deposit of instruments of ratification by four of the signatory governments, namely, the United States, Canada, Iceland, and the United Kingdom. Implementing legislation for this Convention passed the Congress, and was signed by the President on September 27, 1950.

The Convention between the United States and Mexico for the establishment of an International Commission for the Scientific Investigation of Tuna, which was signed at Mexico City on January 25, 1949, entered into force on July 11, 1950, upon the exchange of ratifications by the two Governments.

The Convention between the United States and Costa Rica for the establishment of an Inter-American Tropical Tuna Commission, which was signed at Washington on May 31, 1949, entered into force on March 3, 1950, upon the exchange of ratifications by the two Governments.

Implementing legislation for the two tuna conventions noted above passed the United States Senate on July 26, 1950, and the House of Representatives on August 23, 1950. This Bill was signed by the President on September 7, 1950.

The International Convention for the Great Lakes Fisheries, signed by the United States and Canada on April 2, 1946, is still pending before the Senate Foreign Relations Committee with regard to advice and consent to ratification. It is anticipated that hearings may be held on this Convention during the next session of Congress.

The Convention between the United States and Canada for the extension of certain port privileges to halibut fishing vessels on the Pacific coasts of the two countries, which was signed at Ottawa on March 24, 1950, entered into force on July 13, 1950. Owing to the nature of this Agreement, no implementing legislation is required.

General Fishery Legislation.—A bill to amend title 46, United States Code, section 251, was signed by the President on September 2, 1950. This bill was also designed to serve as a clarification of Section 4.96(a) of the Customs Regulations of 1943. In essence, it will prohibit, except as otherwise provided by treaty or convention to which the United States is a party, any foreign-flag vessel, whether documented as a cargo vessel or otherwise, from landing in a port of the United States its catch of fish taken on board such vessel on the high seas, or fish products processed therefrom; or any fish or fish products taken on board such vessel on the high seas from a vessel engaged in fishing operations or in the processing of fish or fish products.

INTERNATIONAL TECHNICAL COOPERATION

Plans for the Future.—In his inaugural address of January 20, 1949, the President of the United States proposed a program of technical aid to economically underdeveloped countries, commonly known as the "Point Four" program. He envisioned that such a program would be carried out through agencies of the United Nations, agencies of the United States Government, and private organizations and enterprises in the United States. Although considerable planning had taken place in the interim, no formal development of an actual program could take place until the Congress passed the necessary enabling legislation, which was finally accomplished on June 5, 1950, as Title 4 of the new foreign aid bill (Public Law 535).

The United Nations sponsored a meeting in New York in June, at which time representatives of the various governments pledged contributions to a central United Nations fund for carrying out technical aid programs through international agencies such as FAO, UNESCO, and WHO. The United States Government pledged a basic contribution of $10,000,000 and indicated that if the contributions of other governments were sufficient, the United States would increase the contribution to $12,000,000. Following is a summary of available United States funds for carrying out "Point Four" programs during the current fiscal year:

FUNDS AVAILABLE:

Under Information and Education Activities (Public Law 402, 62 Stat. 6: U.S.C. 22431)	$ 2,600,000
Under "International Development Act" (Title 4, Public Law 535, 81st Cong., approved June 5, 1950)	26,900,000
Under "Institute of Inter-American Affairs"	5,000,000
	$34,500,000

ANTICIPATED ALLOCATIONS:

U. S. Contributions to United Nations Program	$12,000,000
Institute of Inter-American Affairs (going projects)	4,000,000
Continuing Programs, U. S. Agencies (SCC)	2,600,000
Organization of the American States, Caribbean Mission, and South Pacific Mission	1,000,000
Department of Commerce Service to Business	400,000
Administration and Program Support (Staffs of participating agencies and Foreign Service)	3,600,000
New projects ("Point Four")	10,900,000
	$34,500,000

It is not possible to forecast at this time what projects in the field of fisheries will be carried on by the Fish and Wildlife Service and the United Nations (FAO) under the program. Many requests and indications of interest in technical assistance programs in fisheries have been received, both by the United States Government and the United Nations. Programs previously carried on in Latin America will be continued and there will undoubtedly be new programs in the Western Hemisphere. It is expected that, for the next year at least, any fishery projects carried out in the Eastern Hemisphere will be those proposed for Asia and adjacent insular areas. Funds will be allocated by the Department of State to the Fish and Wildlife Service for each specific project as soon as negotiations are concluded with the foreign government concerned.

Fishery Mission to Peru.—Early in 1949, on request of the Government of Peru, and in cooperation with the Institute for Inter-American Affairs, the Fish and Wildlife Service sent a short-term mission to Peru to assist in solving numerous problems concerned with administration and management of fish and wildlife resources. In September, the mission was reactivated, and the staff increased by the addition of a fishery technologist and an expert in the management of the fisheries of inland waters for brief assignments. Gratifying progress has been made in attaining the objectives of the project. A large fish terminal is nearing completion in Lima; an experimental technological laboratory at Callao has been completed and staffed; sanitation standards for fishery products established and promulgated; and a management plan for inland waters formulated. It is planned that two Peruvian technicians will be sent to the United States for a year of advanced training in their fields of activity. On the basis of these developments, and others projected for the future, the outlook for increased and more effective use of available stocks of protein foods from the fisheries is excellent.

Fishery Mission to Mexico.—The Mission, which was established in 1942, continued its work with the Mexican Directorate General of Fisheries and Allied Industries, of the Ministry of Marine. The principal project at present is a study of the shrimp fishery in the Gulf of California. The Fishery Institute of the Pacific, located in Guaymas, Sonora, is conducting this study in cooperation with the Directorate General of Fisheries and Allied Industries. Sufficient funds were obtained to recondition and place in operation the Institute's research boat, SHARONAH. The first trip of the SHARONAH was a shrimp-tagging expedition near the mouth of Río Mayo in January, 1950.

The Rockefeller Institute, in cooperation with the Directorate General of Fisheries, conducted some preliminary experiments on the utilization of native species of fishes for pondfish culture. Arrangements have been completed to continue this program for from 1 to 3 years more.

Market Survey of South America.—In June, 1950, the Fish and Wildlife Service cooperated with the Office of Foreign Agricultural Relations of the Department of Agriculture in carrying out a survey of existing and potential markets in Latin America for United States fishery products, particularly canned fish. A team of two specialists of the Service, travelling separately, visited almost all of the countries of South America, and obtained much valuable information on consumption of domestic and imported fishery products, and the outlook for increased markets for products of the United States. The experts also made a survey of the kinds, quantity, and quality of processed fish in each of the countries.

Training Program.—The program of training qualified students of foreign countries in several phases of biological science and management in relation to conservation was continued during the year. Only three students were in residence, all from South American countries, but preliminary arrangements were made for others to start training in the near future. In addition, a special award was made to an official of Thailand for travel in the United States during periods of vacation from an American university, where he was receiving instruction under the sponsorship of his own government. The Service again cooperated with the Department of State in making arrangements for visits of foreign specialists and professors to the United States. A Brazilian expert in fishery biology of inland waters, Dr. F. P. Monteiro, arrived in the United States in early July for a 3-month tour of offices, laboratories, and field stations of Federal and State agencies in the field of fishery conservation.

Several Federal agencies have enlisted the aid of the Fish and Wildlife Service in preparing appropriate itineraries for foreign leaders and specialists, and in some cases there have been transfers of funds to facilitate administration of such tours. Two Portuguese fishery biologists (Dr. Alfredo Ramalho and Mr. Jose Figueiredo) arrived in the United States in June for a stay of 10 weeks under the sponsorship of the Economic Cooperation Administration, to study methods of investigation of sardine resources. General Headquarters, Supreme Commander of the Allied Powers, has sponsored visits by eight national leaders of Japan and the Ryukyus in the field of conservation of fishery and wildlife resources. The Fish and Wildlife Service confidently expects that these visits by foreign scientists and officials will result in a better understanding of the nature of conservation problems and the modern means of solving them, and also in more sympathetic relationships of the peoples concerned.

PHILIPPINE FISHERY PROGRAM

The Philippine Fishery Program, authorized by the Philippine Rehabilitation Act of 1946, was terminated on June 30, 1950, in accordance with the provisions of law. As one of the objectives of the Program was to obtain basic data upon which to build a sound fishery management plan, long-range studies were initiated which obviously could not be completed in the time allotted by the Act. This circumstance required close cooperation with the Philippine Bureau of Fisheries so that the studies could be continued after termination of the United States mission. The most important of the long-range projects were the fundamental investigations in oceanography, fishery biology, and ecology.

In addition to the long-term studies mentioned above, there was need for immediate rehabilitation projects to increase the food supplies from the sea and fresh waters. These projects included exploratory fishing to open new fishing grounds, the introduction of new and more effective gear, modern preservation practices, and experiments in the development of by-products.

By means of news releases, information leaflets, demonstrations, and personal interviews, it was possible to secure immediate results in increasing supplies of fresh-fish products to provide urgently needed proteins. It is estimated that, from a low of less than 1½ ounces of animal protein per person per day at the beginning of the program, the amount nearly doubled and was approaching the point of meeting standard nutritional requirements at the close of the program.

Of the 125 trainess selected by competitive examination for 1 year of training in the United States, 101 have completed training, and are now employed either in the fishing industry or by the Philippine Bureau of Fisheries, where they are making a substantial contribution to the rehabilitation of the fisheries. The remaining 24 will return to the Philippines before October, 1950. In addition to these trainees, a number of student-apprentices of the Philippine Institute of Fishery Technology were trained in the Philippines by employment aboard vessels or in laboratories and pilot plant of the Program, where they worked under direct supervision of technicians of the United States.

During the operation of the Program, more than 30 publications of scientific and popular interest were prepared and distributed. One hundred press releases on the work of the mission were issued, and these were printed by outstanding newspapers and magazines, many translated into the several dialects. So well received was the work of the Program as evidenced by these publications that the Newswriters Association of the Philippines, an organization of editors and feature writers, cited the Philippine Fishery Program of the Fish and Wildlife Service as the outstanding "Marine Development" of the industries of the Philippines during the calendar year 1949.

Largely through the work of the Program, the Philippine Bureau of Fisheries grew from a small division of one of the departments to a full-fledged bureau of the Department of Agriculture and Natural Resources, and was recognized by increased appropriations as one of the major factors in food production. With the close of the Program on June 30, most of the equipment was transferred to the Philippine Bureau of Fisheries, where it is being used to carry on projects initiated by the United States mission. Although the Philippine Bureau of Fisheries is ably administered, and is manned by trained personnel, there is urgent need for continued assistance by technical advisors from the United States.

International Fisheries Commission

The Commission, commonly known as the Halibut Commission, is composed of Messrs. George R. Clark and G. W. Nickerson for Canada; and Messrs. Edward W. Allen and M. C. James for the United States.

The International Fisheries Commission, formed under a convention between the United States and Canada, has continued its program of regulating the halibut fishery of the North Pacific. The success which has attended this program has brought about some complications. The halibut populations have been restored to the extent that the quota allowed to be taken is caught within the period of approximately 60 days, in contrast with the season of 4 to 6 months which prevailed a few years ago. Aside from the economic complications arising from such a short season, there are important biological implications. Leaving the halibut stocks unfinished for 10 months of the year undoubtedly protects certain segments of the population from any utilization whatever, and prevents the cropping which could yield additional poundage for commercial use. However, the Commission lacks authority under the terms of the Convention to split the season or to make other regulations which would have the effect of spreading the fishing activities over a longer period. Recommendations for amendment of the Treaty to give this added power to the Commission have been made by the halibut industry and are under consideration by both the Canadian and the United States Governments.

INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION

The Commission, which is composed of Messrs. Tom Reid, Olof Hanson, and A. J. Whitmore for Canada; and Messrs. Edward W. Allen, Alvin Anderson, and Albert M. Day for the United States, held several meetings during the year to carry out its responsibilities.

The restoration of the sockeye salmon in the Fraser River has been carried forward in a very satisfactory manner during the years since the Commission was organized. Serious threats to its continued success have recently arisen due to the proposals of commercial interests seeking to develop an aluminum industry in British Columbia which will require the generation of a large amount of electricity. In early discussions, some of the most extensive and successful spawning grounds of the salmon have been under study as power sites, thereby creating a grave threat to the success of the Commission's efforts. Special funds were made available to the Commission by both the Canadian and United States Governments during the year to employ fishery biologists and engineers to attempt (1) the assessment of possible damages by the proposed high dams on the major spawning streams, and (2) the location of alternate sites where such impoundments could be made without serious damage to the restoration program.

The fishing regulations promulgated by the Commission for the season of 1950 introduced a new concept in fishery management by closing the high seas west of a line from Bonilla Point to Tatoosh Island, and between the 48th and 49th parallels. This action was taken because the expansion of the fishing areas for the Fraser River sockeye salmon was endangering the rehabilitation work of the Commission. Increasing gear and the development of new fishing techniques in the offshore areas were considered to be only a challenge to foreign nationals to take fish off North American shores. The closure by the Commission of these high-seas waters was considered to be the logical preventive remedy to this situation.

Rehabilitation of barren areas was continued by the planting of fish raised at the Quesnel field station. As more information is obtained and as the field station continues in the production of fish by artificial means, the restoration of streams which once produced large stocks of salmon, but which in recent years have had virtually no spawners, holds considerable promise for the ultimate successful rehabilitation of the valuable Fraser River fishery.

INTER-AMERICAN TROPICAL TUNA COMMISSION

The Commission convened for its first meeting in Coronado, California, July 18, 1950, with Commissioner José Cardona-Cooper representing Costa Rica, and Commissioners Lee F. Payne and Eugene D. Bennett representing the United States. Commissioners Virgilio Aguiluz and Milton C. James were not present. Dr. Cardona-Cooper was elected Chairman, and Mr. James, Secretary, for the first fiscal year. Other business of the meeting concerned the adoption of recommendations on program and budget for consideration by the two governments. It is confidently expected that details of the program will be announced prior to the next meeting of this Society.

GREAT LAKES COMMITTEES

Lake Trout Committee.—The committee was organized on December 8, 1943, at a meeting attended by representatives of Illinois, Indiana, Michigan, Wisconsin, and the U. S. Fish and Wildlife Service. The Province of Ontario has participated since 1946.

The purpose of the committee was to determine the importance of planting programs in maintaining populations of lake trout. It was decided at the first meeting to initiate a program of cooperative research, and the procedure for joint action was determined. Plans were made for a 6-year program, although it was recognized that more time would be required to reach final conclusions. A progress report at the end of the period was prepared by Dr. John Van Oosten, and published in *The Fisherman,* Vol. 18, Nos. 5 and 6, 1950.

Sea Lamprey Committee. — This committee was organized at St. Paul, Minnesota, on September 10, 1946, by a group of representatives of New York, Pennsylvania, Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota, Province of Ontario, and the Fish and Wildlife Service. The purpose was to organize and integrate research and control programs of the several agencies, thus insuring complete coverage without duplication of effort. Annual meetings have been held to review progress and to exchange pertinent information. It is confidently expected that the program now in operation, with periodic adjustments and refinements, will lead to attainment of the objectives of the committee. The present chairman is Dr. James W. Moffett, Fish and Wildlife Service, Ann Arbor, Michigan.

FISHERIES OF THE TRUST TERRITORY

The Fish and Wildlife Service, under the program of Pacific Oceanic Fishery Investigations, has carried on extensive explorations and experimental fishing in the Pacific area, including the area about the Trust Territory. Contrary to expectations, there has been no considerable interest shown by established fishing companies, and local enterprises have been largely unsuccessful in taking tuna.

As related elsewhere in this report, the Japanese Government was authorized in May, 1950, to extend tuna fishing operations southward to the equator. A Fish and Wildlife Service observer went aboard one of the Japanese vessels for an extended voyage to obtain information on methods of fishing, handling, and preservation, and to record biological data on tunas. It is hoped that this project will yield much information of value in further development of the tuna fishery in the waters of the Trust Territory.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

The following report of the activities of FAO concerning fisheries during the past year was submitted by Dr. John L. Kask, Chief Biologist of the Fisheries Division:

The Fifth Session of the FAO Conference was held in Washington in November, 1949. Among the important decisions made by the Conference was that of moving the headquarters of the Organization from Washington, D. C., to its permanent headquarters in Rome, Italy. The move will be made early in 1951.

Commission II of the Conference dealt with the program of work and the FAO program for technical assistance for economic development. The Commission was divided into eight panels, one for each technical division of the Organization. The Fisheries Panel, with Mr. A. W. Anderson of the United States of America as Chairman and Dr. M. K. El Saby of Egypt as Vice-Chairman, reviewed the progress of work of the Fisheries Division and considered the program for 1950. The program of work covers the following features: (1) collection, analysis, and dissemination of information on fish-cultural methods, fishing methods and gear, commodity studies, fishery research and educational institutions, fisheries resources, landing and trade statistics, nomenclature of commercially important fishes, and commodity standards; (2) promotion of international consultation through the establishment of additional regional fisheries councils and the servicing of existing and future regional councils; (3) direct technical aid through consulting services, technical meetings, and the publication of information on technical aspects of fisheries.

In September, 1949, at the invitation of the Director-General of FAO, a meeting was held in Rome to consider the establishment of a regional fisheries council for the Mediterranean. Under the chairmanship of Ambassador Sola of Italy and the vice-chairmanship of Professor Jean LeGall of France, the delegates of France, Greece, Italy, Lebanon, Turkey, the United Kingdom, and Yugoslavia unanimously adopted a resolution recommending that the agreement which was formulated for the establishment of the General Fisheries Council for the Mediterranean be accepted by their governments. The agreement is similar to that which established the Indo-Pacific Fisheries Council, and acceptance by the Governments concerned is expected soon.

At a meeting convened at The Hague, Netherlands, at the end of August, 1949, FAO brought together representatives of the major fishing countries of Europe and North America to discuss economic problems related to the production and distribution of herring and similar species. The meeting recommended that market research be carried on by the FAO secretariat, and suggested that FAO call a meeting of fishery technologists to continue an examination of processing methods with a view to encouraging new techniques. The technical problems associated with the processing and utilization of herring will be discussed at a meeting on herring technology being called by FAO during the latter part of September, 1950, in Bergen, Norway. The United States will be represented by Mr. Harold E. Crowther, Fish and Wildlife Service (Delegate), and Mr. Herbert C. Davis, of Terminal Island Sea Foods Ltd. (Advisor).

During the past year, the FAO Fisheries Division continued to publish the bimonthly *Fisheries Bulletin* in English, French, and Spanish editions, and in January, 1950, introduced the first number of the *World Fisheries Abstracts* also in the above three languages. This is a bimonthly review of technical literature on fisheries and related industries. The 1950 *Yearbook of Fisheries Statistics* which includes production and trade statistics of most fishing countries went to press in the early summer. Separate publications issued or prepared by the Fisheries Division during the past year include *Report of the FAO Fisheries Mission for Thailand,* a chapter on Latin American fisheries appearing in the report of the Joint ECLA/FAO Working Party entitled *Agricultural Requisites in Latin America,* the fisheries section of the UN *Mission to Haiti* and *Report on a Fisheries Project for Costa Rica* which was prepared by the Division for limited circulation. The *Proceedings* of the inaugural meeting of the Indo-Pacific Fisheries Council were published in Singapore during the year.

INDO-PACIFIC FISHERIES COUNCIL

The Second Annual Meeting of the FAO-sponsored Indo-Pacific Fisheries Council was held in Cronulla, Australia, in April, 1950. The Council elected Dr. J. D. F. Hardenberg of Indonesia as Chairman and Dr. D. V. Villadolid of the Philippines as Vice-Chairman. Accomplishments of the meeting included: arrangements for providing FAO with information concerning national fisheries programs and the enlistment of experts for consultation in the region; a report to guide governments requesting technical assistance; arrangements for coordinating tuna research of various countries in the area; arrangements for furthering the expansion of fish culture in the region; and collaboration in fisheries matters with the South Pacific Commission. The United States was officially represented by Mr. O. E. Sette (Delegate) and Mr.

Charles Butler (Alternate), both of the Fish and Wildlife Service. It is expected that the next meeting of the Council will be held in Madras, India, February 1-16, 1951.

ECONOMIC COOPERATION ADMINISTRATION

It is gratifying to note that the fishing industries of most European countries have largely recovered from the disorganized conditions resulting from World War II, and can be expected to operate successfully with little if any outside assistance. In Greece and Turkey, there is further need for aid in an orderly development of modern methods of marketing. The program carried out under the direction of Robert A. Nesbit, as related in the last report of the Committee, is being continued under the direction of Milo Moore.

Late in 1949, plans were made for a Korea Technical Institute to assist South Korea in agriculture, fisheries, and engineering. The Institute was organized by the Illinois Institute of Technology, under contract with ECA. The project included plans for a fishery school in Pusan, with three instructors. The staff of 24 scientists and technicians arrived in Seoul in June, 1950, two days before the invasion of South Korea, and were soon evacuated. It is not unlikely that the Institute will be re-established when conditions in Korea become suitable for effective operation. R. H. Fiedler had also been assigned to Korea to assist in rehabilitation and development of the fisheries, but was diverted to Indonesia to make a survey of the industry in that area.

In April, 1950, Robert W. Tyson made a survey of the fishing industry of Angola with respect to present and potential capacity, and the need for assistance to insure proper development. An illustrated report on the survey was published in *Commercial Fisheries Review* for August, 1950 (Volume 12, Number 8).

ADMINISTRATION OF JAPANESE FISHERIES

The following detailed statement of recent significant developments was supplied by Mr. William C. Herrington, Chief of the Fisheries Division, General Headquarters, Supreme Commander of the Allied Powers (SCAP):

Production. — The past 12 months have witnessed the successful development of the intensive program for rehabilitation of the Japanese fisheries which has been encouraged and assisted by SCAP. The Japanese fishing fleet, except for specialized units such as that engaged before the war in crab fishing, has been restored to a level somewhat above that existing in 1940. Supplies of imported materials such as petroleum, and manila and cotton fiber have been sufficient to permit full utilization of the area now authorized for Japanese fishing operations. These developments served to increase aquatic production in

1949 to a level approaching that reached during the prewar years. Production of sardines still is much below the prewar level, but that from other fisheries is considerably higher. As a result of increased production, the supply of fish in the markets has been sufficient to meet the Japanese food requirements at the relatively high levels at which prices had been controlled. Consequently, all controls on fish prices were removed on April 1, 1950. With the further increase in production which has occurred during the first half of 1950, there has been a drop in most fish prices considerably below the former price-control levels.

Research.—Considerable progress has been made in reorganizing the Japanese Fisheries Research system to place greater emphasis on population studies to determine how to prevent overexploitation and develop the maximum sustained yield. Implementation of the reorganization laws passed in 1948 is being carried out as rapidly as finances and personnel permit. The Research Department and Research Stations of the Fisheries Agency have been reorganized to provide eight regional laboratories, each of which will handle the research problems of greatest importance to its region. Buildings are being constructed or renovated to take care of the regional laboratories, and research staffs are being organized. The principal limitation is in qualified personnel. Emphasis is placed on coordinating the research programs carried on by various agencies in such major fisheries as sardines, skipjack, tuna, herring, and the trawler fishery of the East China Sea. In the latter area, considerable progress has been made over the past 3 years with funds coming from the trawling association and national government. Japan now has the framework for an excellent fishery research program, but it will take some time to secure and train an adequate and qualified staff of research people.

Control of Overfishing.—On April 30 and May 1, 1950, the two houses of the Japanese Diet passed a Law for the Prevention of Exhaustion of Marine Resources. Under the authority contained in this law, the Minister of Agriculture and Forestry is empowered to regulate the number of fishing vessels engaged in any fishery in order to prevent depletion of stocks. The first fishery to be affected by this law is the East China Sea trawl fishery.

By July 10, 1950, the first major step in the reduction of the East China Sea Trawl fleet had been completed. Under the authority contained in the Law for Prevention of Exhaustion of Marine Resources, public hearings were held in Tokyo on June 8 and in Fukuoka on June 23. At these hearings, standards for the selection of vessels, and the licenses of which would be cancelled or restricted, were adopted, and owners were given an opportunity to express their views. Thereafter, effective July 10, the licenses of 62 bull trawlers and one otter trawler were cancelled. Sixteen operators were affected. Effective the same date, operation of 110 bull trawlers of less than 50 gross tons was restricted to the area bounded by Longitude 130° and 127° 30′ E., and Latitude 25° N., excluding the Sea of Japan north of Latitude 36° N. Fifty-five operators were affected. Prior to these actions on July 1, the Japanese Government cancelled the licenses of 17 vessels suspected of violation of the provisions of SCAPIN 2046, and the owners of seven other suspected vessels voluntarily surrendered their licenses.

Fishing Areas.—SCAP has consistently impressed the Japanese government and fishing industry with the fact that extension of the fishing area is closely related to the progress made in the control of overfishing in the present area and the effectiveness of the enforcement of SCAP restrictions on fishing areas. Progress made during the past year through the development of a more effective patrol system, organization of an improved research program on overfishing problems and reductions on the excessive East China Sea trawl fleet, has been recognized by two SCAPINs which relax limitations on Japanese fishing operations.

SCAPIN 2046, 19 September 1950, extended eastward to longitude 180° between latitudes 24° and 40° N., the area in which Japanese fishing operations are authorized. This extension opened to the Japanese tuna fishermen an area which had been fished primarily for albacore during years before surrender. During the first season, from November, 1949 to mid-February, 1950, about 2,660,000 pounds of albacore, as well as 3,500,000 pounds of other tuna, marlin, and shark were produced.

SCAPIN 2097, 11 May 1950, authorized mothership-type tuna fishing expeditions in an area south of the area authorized for general fishing operations. This authorization did not constitute a general extension of the area, but merely permitted a specific type of fishery to be conducted in a new area. Vessels were not allowed to approach nearer than 3 miles to land areas. Provisions were made for close control of operations by a representative of SCAP who would accompany each expedition. The Japanese Government was permitted to dispatch research vessels with each expedition to collect scientific information which would be used in establishing regulations to insure sound management of the fishery. By August 26, two expeditions, one consisting of a 10,000 gross-ton refrigerator ship and 25 catchers, and one consisting of a 3,000 gross-ton refrigerator ship and 12 catchers, had processed about 7,000,000 pounds of tuna, marlin, and shark. About 30 percent of this total was yellowfin tuna frozen in the round. The larger expedition had operated for 10 weeks, the smaller for 6 weeks.

Organization of Cooperatives.—Based on the provisions of the Fisheries Cooperative Association Law, enacted by the Diet November 27, 1948 and activated February 15, 1949, organization of democratic fisheries cooperatives along lines of accepted international concepts began in April, 1949. As of July 31, 1950, 4,389 cooperatives were organized, with 780,000 members, and were actively carrying on general business activities such as purchasing materials, selling members' catch, acting as savings depositories, extending credit, and the like. Of this number, 3,962 were general fishermen's cooperatives, 197 were production cooperatives, and the remaining 230 were cooperatives for processing marine products.

In accordance with provisions of a companion law, the former 3,120 government-controlled fisheries associations in existence as of February 15, 1949, were compelled to cease all business functions (except those related to fishing rights held by the associations) as of October 15, 1949. As of July 31, 1950, approximately 60 percent of these associations had completed final disposition of assets, the major portion of which were transferred to the new cooperatives. Facilities owned by the associations were valued at approximately 7,700 million yen.

By the end of July, 1950, 109 federations of cooperatives had been organized. Of this number, 82 were federations of general fishermen's cooperatives, 10 were federations of processing cooperatives, 15 were credit federations of fishermen's cooperatives, and 1 was a credit federation of processing cooperatives. Under the law, production cooperatives are not permitted to federate as such, but may become members of federations of fishermen's cooperatives. The credit federations engage solely in deposit and loaning activities.

Many of the smaller cooperatives are experiencing financial difficulties at present. This is related to the generally difficult economic conditions in the fishing industry resulting from decline in the price of fish, and the increased cost of supplies with the cessation of subsidies on cotton and petroleum imports. Some amalgamation of small cooperatives into larger units is in process.

Minor amendments to the cooperative law were enacted by the Diet in May, 1950, one of which permitted small juridical bodies to become associate members. All fishery companies had been barred previously.

The Fisheries Law and Rights Reform.—The basis for reform of the fisheries rights system of Japan became established by Diet enactment of the Fisheries Law (No. 267 of 1949) on November 29, 1949. The Law was activated March 15, 1950. This law provides for complete reformation of the fishing rights system of Japan by:

(a) Providing for cancellation of all existing fisheries rights within 2 years, with the holders of such rights to be compensated in government funds maturing over a 25-year period.

(b) Improving utilization of fishing grounds by issuance of rights on the basis of current conditions and fishing techniques.

(c) Authorizing three types of rights, namely common fishery, fixed net, and demarcated. All subleasing is prohibited and the holder pays an annual use fee. Two types of licenses are also to be issued: coastal waters and deep-sea fisheries.

(d) Establishing fisheries adjustment commissions, one in each fishing region (sea area).

(e) Providing for final cancellation of old rights and issuance of new rights to be completed March 15, 1952.

Sea areas, as authorized under the Fisheries Law, were established by the Fisheries Agency in May, 1950. A total of 179 areas were set up on the basis of common fishing practices, economic conditions, and biological relationships.

Election of the Sea Area Adjustment Commissions was held August 15, 1950, with 88.6 percent of the eligible fishermen casting their ballots. Each commission is composed of 10 members, 7 of which were elected by the fishermen residing in the area, and the other 3 appointed by the respective prefectural governor. Special consideration was authorized by law for Hokkaido, where commissions have 14 members, with 11 elected by the fishermen.

The Central Fisheries Adjustment Council was appointed by the Minister of Agriculture and Forestry, and approved by the Cabinet on June 12, 1950. This Council is established for the purpose of guiding and advising the Japanese government in the administration of the Fisheries Law.

INTERNATONAL WHALING COMMISSION

The International Whaling Commission (established pursuant to the International Agreement for the Regulation of Whaling signed at Washington, December 2, 1946) held its second annual meeting at Oslo, Norway, July 17-21, 1950. Commissioners and advisors of the following countries attended: Australia, Brazil, Canada, Denmark, France, Iceland, Mexico, Netherlands, Norway, Panama, South Africa, Sweden, United Kingdom, U.S.A., and U.S.S.R. The Commissioners from Panama and New Zealand were absent. Argentina and Chile have not ratified the agreement, but were represented by observers. Observers also represented the United Nations Food and Agriculture Organization, the International Council for the Exploration of the Sea, the Supreme Commander for the Allied Powers, Tokyo, and the Association of Whaling Companies.

The U.S.A. was represented by Dr. A. Remington Kellogg, Director of the U. S. National Museum, *Commissioner;* Dr. Hilary J. Deason, Fish and Wildlife Service, *Deputy Commissioner;* and Fred E. Taylor, Department of State, *Advisor.* Canadian representatives were Miss Burwash, Embassy of Canada at Oslo, *Acting Commissioner,* and Dr. R. Fisher, Fisheries Research Board of Canada, *Advisor.*

The Commission considered in detail statistics on the Antarctic catch compiled by the International Bureau for Whaling Statistics, Sandefjord, Norway. In the Antarctic season of 1949-50, 29,015 whales of all species were taken (equal to approximately 16,000 blue whale units exclusive of sperm whales). In addition, 3,000 whales of all species (equal to about 1,200 blue whale units) were taken by land station operations. The majority of the whales taken were fin whales, and the proportion of blue whales in the total take was less than in any previous Antarctic season, although the average length of the blue whales was greater than in previous seasons. The average size of fin whales showed a slight decline. The total catch included 6,181 blue whales, 20,034 fin whales, 2,143 humpback whales, 1,286 sei whales, and 2,727 sperm whales. The baleen production in the Antarctic during the 1949-50 season, including the production of land stations, was 2,159,148 barrels, a decline compared with previous seasons. The yield of oil per baleen whale showed an increase.

The decrease in the proportion of blue whales, the largest and most productive species in terms of oil, gave the Commission considerable concern. Although the Antarctic quota of 16,000 blue whale units may have had some general effect on the conservation of whale stocks, apparently it does not halt the decline in the abundance of blue whales. The Commission decided to take under advisement for consideration at its 1951 meeting the question of whether quotas should be established for each species.

The Commission considered the question of giving further protection to the sperm whales in tropical waters in order to give protection to females and calves. Additional data are to be accumulated as a basis for possible adoption of amendments to regulations respecting sperm whales in the 1951 meeting.

The Commission gave a great deal of attention to research and technical matters, and agreed on a number of recommendations with respect to scientific investigations which are to be conducted by existing agencies of Member Governments. Of particular importance is the Commission's decision that all possible means should be explored for increasing the studies of whale migrations. A number of minor amendments to the international regulations were adopted which are mainly intended for purposes of clarification and to facilitate administration of the regulations.

The third annual meeting of the Commission will convene at Cape Town, Union of South Africa, on July 23, 1951.

Fur Seals

It will be recalled that the Japanese Government in October, 1940, gave notice to the United States, Canada, and the U.S.S.R. of her intention to abrogate the Fur Seal Convention of 1911, and such abrogation became effective one year from the date of that notice, namely in October, 1941. The chief argument advanced by Japan as a basis for her abrogation was that the seals had increased in abundance so that they were damaging fishery resources vital to Japan.

Although the United States and Canada concluded a provisional agreement to protect fur seals as soon as possible after Japanese abrogation became effective, it was recognized then, and is recognized now, that it would be desirable eventually to conclude another agreement among the parties to the 1911 agreement.

The Natural Resources Section of General Headquarters of the Supreme Commander for the Allied Powers undertook the task of obtaining all possible information on Japanese fur-sealing activities and conducted research to support or refute Japanese claims made at the time of abrogation of the 1911 agreement.

A report was issued in July, 1950, by the Natural Resources Section of SCAP which gives the results of these investigations. The investigations were conducted and the report prepared by Oliver L. Austin, Jr. of the Fisheries Division, Natural Resources Section, and by Ford Wilke, Branch of Wildlife Research, Fish and Wildlife Service, who was assigned to the Natural Resources Section during 1949 and 1950 to assist in the investigations.

The report is an excellent summary of the history of Japanese fur-seal operations. It disclosed, much to the astonishment of many, that the Japanese conducted pelagic sealing on a rather large scale for at least 10 years before she abrogated the 1911 agreement. These operations were openly in violation of one of the primary provisions of that agreement, namely the abolition of pelagic sealing. The report, although based upon limited data on the distribution, abundance, and food habits of the fur seals in Japanese waters, contains information which would be of importance in the negotiation of any new international fur-seal agreement. In particular, it does not indicate that the fur-seal herds inflict any significant damage on Japanese fishery resources utilized for food by the Japanese people. The report also describes, in detail, pelagic methods used by the Japanese and denotes that the techniques used during the years immediately before the end of the war in 1945 were extremely efficient. The report, while not as complete as could be desired, contains much valuable information, and indicates the need for further intensive research.

INTERNATIONAL CONFERENCES

International Council for the Exploration of the Sea.—The thirty-seventh annual meeting of the Council was held at Edinburgh, Scotland, October 3-11, 1949. More than 100 delegates and expert advisors from the member countries, and observers and guests from other countries and organizations were present. The official observer for the United States was Dr. William F. Royce, Fish and Wildlife Service.

Reports of significance dealt with the herring fisheries, periodic changes in water and air temperatures in the Spitzbergen area, with effects on the cod fishery, the bottom fisheries and need for conservation in the North Sea, and the use of echo sounders in locating schools. Plans for coordinating the research efforts of several countries were discussed, and the outlook for success is good. Deliberations of the Council were held in an atmosphere of helpful cooperation, a fact which perhaps explains the long and happy history of this organization, which will celebrate its fiftieth anniversary in 1952. The thirty-eighth meeting will be held in Copenhagen, October 2-10, 1950. Dr. L. A. Walford, Fish and Wildlife Service, will be the official observer of the United States.

Indian Science Congress.—The thirty-seventh annual session of the Congress, devoted to all fields of science, and with delegates from many countries, was held at Poona, January 2-7, 1950. Fishery problems of India were discussed by Dr. S. B. Setna, Director of Fisheries, Bombay. He emphasized the need for application of scientific principles to the everyday problems of the fishermen.

Gulf and Caribbean Fisheries Institute.—The Institute, which was organized and held its first meeting in 1948, convened for the second time in Miami Beach, November 15-18, 1949. Delegates from the United States and some of the countries touching Gulf of Mexico and Caribbean Sea waters were in attendance. The sessions were devoted almost exclusively to technical problems of the area. The third annual meeting is scheduled for Miami Beach, November 13-17, 1950.

Latin-American Congress of Marine Biology.—The first meeting of this new and promising organization was held at the Technical University of Federico Santa Maria, Valparaiso, Chile, October 10-14, 1949. Countries and organizations represented were Argentina, Brazil, Chile, Ecuador, Mexico, Peru, Panama, Uruguay, and UNESCO. According to the organizer of the Congress, Dr. Parmenio Yañez, Director of the Montemar Institute, the objective of the meeting was to bring together all marine biological specialists for the purpose of creating a permanent entity for the collection and diffusion of scientific information, which would permit recognition, appreciation, and protection of the riches of the sea. It is planned to hold meetings periodically, perhaps every 3 years.

International Union for the Protection of Nature.—The next meeting of the Union will be held at Brussels, Belgium, October 18-23, 1950. The United States will not be represented by an official delegation. Among those who will attend are: Messrs. Victor H. Cahalane, National Park Service; Harold J. Coolidge, National Research Council; Harold W. Glassen, Michigan Conservation Commission; L. A. Walford, Fish and Wildlife Service; and Richard W. Westwood, American Nature Association.

THE COMMITTEE ON NATIONAL-STATE RELATIONS

O. L. Meehean

The West Virginia Case

At the 78th annual meeting of the Society in Atlantic City in September, 1948, Mr. Wayne D. Heydecker, Secretary-Treasurer, Atlantic States Marine Fisheries Commission, outlined very ably the development of interstate compacts on pollution and fisheries. He also discussed the tidelands decision of the Supreme Court, which asserted that the Federal Government had an over-riding interest in and to the oil and other natural resources in the bed of the sea, but left untouched the right of States to adopt regulations covering marine fisheries so long as they did not conflict with a Federal statute and the Federal Constitution.

He also described the *Toomer* vs. *Witsell* case in South Carolina, which raised the issue as to whether the tidelands decision divested South Carolina of her authority to regulate fisheries within her territorial waters. The decision in this case made it clear that the States retain the power to regulate fisheries within their territorial waters under police power unless such regulation conflicts with federal regulations.

During the past year the Supreme Court of Appeals in West Virginia has ruled that ratification and enactment into law of the Ohio River Valley Water Sanitation Compact was unconstitutional as a violation of the Constitution of West Virginia. Present plans call for the Commissioners of West Virginia, supported by the Ohio River Compact States, to petition the U. S. Supreme Court for a review of this decision.

I bring this case to your attention because the decision of the West Virginia court may stand as a precedent for the proposition that local constitutional provisions may, inferentially, limit the power and authority of any State to enter into compacts with other States. It may also stand as a precedent for the theory that the validity of an interstate compact is continuously subject to varying interpretations which may be given to its provisions by the courts of the participating States. If permitted to stand, the West Virginia decision may be brought forward and accepted as authority for holding unconstitutional any of the current fishery compacts, water pollution abatement compacts, water allocation compacts, the New York Port Authority, and many other cooperative projects which have been undertaken by various groups of States. The principle would, no doubt, deter other States from looking to the compact clause of the Constitution of the United States for means of solving problems which project beyond State lines.

CORPS OF ENGINEERS

The civil works program of the Corps of Engineers provides approximately 27,000 miles of river improvements, primarily for flood control and related purposes, having a combined water surface of approximately 1,250,000 acres. To secure maximum benefit from the resources on these developments, the Corps works in close cooperation with the States and the Fish and Wildlife Service, correlating the requirements of all these interests in the planning, construction, and operation of each project.

Under the leadership of State conservation agencies, the North Dakota Reservoir Use Advisory Committee, the Tri-State Fisheries Committee, the Upper Mississippi Conservation Committee, and the Oklahoma Fish and Game Council investigate fish and wildlife problems in connection with flood control and navigation projects of the Corps. The States also have an important function in the inter-agency planning committees established to coordinate the interests involved in water-development projects on major river basins.

Investigations by State and Federal agencies have been advanced by materials, equipment, services, personnel, and operating expenses supplied by the Corps of Engineers. Lands having particular value for procedures in carrying out the programs of the States or of the Fish and Wildlife Service for the management of game and fish resources may be made available to the States or the Service.

BUREAU OF RECLAMATION

The Bureau of Reclamation works closely with the Fish and Wildlife Service and the States in connection with the investigations and planning of new projects so that they will provide maximum collateral benefits to fish and wildlife, consistent with the primary purposes of each project under consideration. Public Law 732 (Seventy-ninth Congress, approved August 14, 1946) requires close cooperation with the Fish and Wildlife Service and with the States, and provides for non-reimbursable allocations of appropriate portions of the costs of new projects to conservation of fish and wildlife.

Where major conflicts in the views of those interested or concerned in the proposed projects appear imminent, the Bureau of Reclamation holds public hearings to solicit publicly the views of all concerned in order to provide a basis for making a decision on controversial matters.

The cooperative studies started during the planning stage are continued through the design, construction, and operation stages. Fish hatcheries that have been constructed by the Bureau of Reclamation have been immediately turned over to the Fish and Wildlife Service or to State conservation commissions for operation and maintenance.

In the Central Valley Project in California, the Bureau of Reclamation is cooperating with the Fish and Wildlife Service and the State conservation department in investigations, planning, and design of structures, to prevent fish from being pumped from the river into the Delta-Mendota Canal.

U. S. FOREST SERVICE

Since many States are cooperating now with the U. S. Forest Service in connection with fishing as a recreational use on national forests, members of the Society are familiar with their policies. The existing cooperative wildlife management programs, which include fisheries management, continue to expand.

In Virginia, in addition to the extension of programs into new areas, a special study was carried on in cooperation with the State to determine methods of stream management that would distribute the take of legal-sized fish plantings over a longer period of time.

In California, the Forest Service cooperated with the State on streamflow improvement work and on the determination of minimum flows to be maintained below various impounding structures.

West Virginia, in cooperation with the Forest Service, has been conducting a beaver management program, in which all waters are classified according to their importance for beaver and trout production.

FISH AND WILDLIFE SERVICE

The trend toward the solution of major problems by interstate compact, in which the Federal Government acts in an advisory capacity, as a participant, or as a coordinator, continues. Public Law 66 (81st Congress, May 19, 1949) authorizes a compact of the five States bordering the Gulf of Mexico. Article VII of the compact is quoted in full:

> The Fish and Wildlife Service of the Department of the Interior of the Government of the United States shall act as the primary research agency of the Gulf States Marine Fisheries Commission cooperating with the research agencies in each state for that purpose. Representatives of the said Fish and Wildlife Service shall attend the meetings of the commission. An advisory committee to be representative of the commercial salt water fisherman and the salt water anglers and such other interest of each state as the commissioners deem advisable may be established by the commissioners from each state for the purpose of advising those commissioners upon such recommendations as it may desire to make.

Section 2 of Public Law 249 (81st Congress, August 18, 1949) directs the Fish and Wildlife Service to undertake a continuing study of the shad on the Atlantic Coast. Interested Atlantic Coast states are represented on an advisory committee to discuss research programs with the Service's biologists.

Section 3 of Public Law 249 authorizes the Fish and Wildlife Service to study the sea lamprey of the Great Lakes with the ultimate objective of controlling the abundance and spread of this predator on commercially valuable fishes. Excellent cooperative understandings with the eight Great Lakes States, the Province of Ontario, and several educational institutions are in effect.

Between July 1, 1949, and June 30, 1950, the Fish and Wildlife Service issued 266 reports on water-use projects — 130 on Corps of Engineers developments, 57 on work of the Bureau of Reclamation, 7 on watershed improvements of the Soil Conservation Service, and 72 on public and private waterpower projects subject to license by the Federal Power Commission. These reports were prepared after studying projects in cooperation with State agencies. In some cases, such as the Rogue River in Oregon, reports are issued jointly by the State and the Fish and Wildlife Service. On certain sites in the Missouri River Basin, State biologists have worked with the Service in selecting sites for wildlife food and cover plantings and in recommending measures to replace bottomland cover which will be inundated by reservoirs.

A cooperative fishery research unit has been established at Colorado A. and M. College, Fort Collins, Colorado. This is the first unit of its type and is patterned after the wildlife research units which have been in existence for a number of years.

The Fish and Wildlife Service has about 92 cooperative agreements with the States for the operation and better utilization of the output of Federal hatcheries. In 40 States, Federal fish applications are reviewed as to the propriety of species and need for stocking. About 52 agreements deal with the use of facilities, exchange of equipment, and coordination of activities.

TVA biologists have assisted the State conservation departments in Mississippi, Georgia, North Carolina, Kentucky, and Tennessee in lake investigations and on fishery management problems. The State of Tennessee is conducting a creel census on Little River in the Great Smoky Mountain National Park to secure information regarding fishing and fish management in the park.

The State of Wyoming has entered into a policy agreement with the Soil Conservation Service with regard to construction and subsequent management of farm and stock-watering ponds and the development of their fishing potentialities. Wyoming is also operating agreements with Colorado and Idaho wherein State waters which head outside the State, where the stream is generally fished, may be planted by adjoining States as a means of keeping fishing waters properly stocked.

Kentucky and Tennessee have reached an agreement whereby, on the Dale Hollow and Kentucky reservoirs, fishing licenses issued by either State will be recognized as legal by the other.

The Atlantic Sea-Run Salmon Commission continued its investigations. Stream surveys including a study of the migration pattern of adults and smolts, environmental conditions, and relation of food organisms to survival, occupied a large proportion of their activities. A larger number of Atlantic salmon of various sizes was planted than in past years.

POLLUTION

The Ohio Valley States have been actively engaged in cleaning up pollution in the Valley. Ohio has reinforced its control laws, effective August, 1949. Kentucky, with the help of the Ohio River Valley Water Sanitation Commission, has designed more adequate legislation, which became effective in June, 1950.

The Ohio River Valley Water Sanitation Commission has been working in a number of fields. This organization is actively pursuing the acid mine waste problem, which looms very large in the Valley. As a result of notices sent to industries a number of industries have set up action committees to cope with waste problems. The Commission has set minimum standards for the treatment of sewage and trade wastes at a number of points on the Ohio River. Surveys of the Wabash River between Illinois and Indiana were completed with the cooperation of these States and the U. S. Public Health Service. A research project designed to control phenol wastes at the source was set up at a pilot plant provided by the Armco Steel Company. This experiment is being performed by the Commission in cooperation with the Ohio State Department of Health, Armco Steel Company, Wallace and Tiernan Company, Wellsbach Company, and Mathieson Chemical Company. It is partially financed with funds provided through the U. S. Public Health Service.

The Interstate Commission on the Potomac River Basin is actively prosecuting the solution to the pollution problem on the Potomac in the Washington, D. C., metropolitan area. Plans have also been made and initial action taken to carry out a general soil conservation program on the Monocacy River to control erosion. This is intended as a demonstration of what can be accomplished by the concerted action of local cooperative organizations.

The report of this committee does not cover the entire accomplishment in the field of state and national relations since these accomplishments are so numerous and far-flung that only a limited number have come to our attention.

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

George E. Butler

To compile a report covering activities in the fields of hydrobiology and fish culture on the North American continent required much assistance from many sources. This assistance, and suggestions for the form the report might take, have been freely given, and are gratefully acknowledged.

It was suggested that the report might contain a brief account of research and interesting experiments in fish culture being carried on in different parts of the continent. It was felt that such a report would provide useful information, and in addition might prevent duplication of effort. The suggestion was acted upon and the appropriate officials contacted in the different states and provinces. Assembling the information obtained was a problem, but it was decided to present the material on a geographical basis.

In order to do full justice to the information received from correspondents, and to serve the best interests of the membership, a rather complete compilation of reports from all responding agencies and workers has been mimeographed. Copies are being distributed to all members in attendance here.

Since these detailed reports are available it may be sufficient to present, for the Transactions, only a brief, generalized summary of what appear to be dominant trends in the field.

Studies of fish populations, yields from both natural and artificial propagation, and fish migrations and movements are being supported by many states and provinces. Statistical methods, and techniques for marking and recovering fish, are undergoing continuous refinements.

The feasibility of increasing fish production in small inland waters by addition of chemical fertilizers is being widely explored. Possibilities for the control of aquatic plants, by both chemical and mechanical means, are being investigated in many parts of the country.

Fish cultural advances in terms of improved hatchery diets and practices, and more careful adjustment of stocking to carrying capacities of waters, have been reported by many agencies. Progress in the recognition and treatment of fish diseases, especially in the crowded conditions of hatcheries, has been especially gratifying.

Recent expansion of investigational facilities in several seaboard areas has resulted in accelerated progress in marine fisheries work. Throughout the commercial field, both marine and freshwater, emphasis is being placed on a fuller utilization of resources.

A glance at the range of topics covered in the detailed mimeographed report supports the optimistic belief that almost every agency concerned with fisheries is operating on a scale which may almost make up for the years of World War II when such work sank, perforce, to a low productive level. The prospect for advances in the near future is exciting.

COMMITTEE ON COMMERCIAL FISHERIES

A. W. Anderson

The commercial fisheries of the United States were maintained at a high level during 1949. The United States and Alaska catch of fishery products amounted to about 4.8 billion pounds, valued at nearly $325,000,000 to the fishermen. The volume has been exceeded only by the 1941 catch of 4.9 billion pounds, and the value, despite a general decline in the price of fishery products, only by the 1948 total of $367,000,000. Processing increased the value of the fishermen's catch to $601,998,000, and distribution to $769,663,000, while the ultimate consumer paid about $996,613,000.

About 165,000 fishermen, a new record for the United States, manned over 9,000 documented vessels of 5 tons and over, about 40,000 motorboats, and 35,000 other boats. In addition, about 2,000 transporting craft were operated by 4,000 men. Shore workers numbered 110,000 in about 4,000 shore plants. There were about 300,000 indirectly employed in allied industries such as gear manufacture, ship building, processing equipment, and fuel, food and maintenance services. Vessels added to the fleet numbered 1,002.

Menhaden, taken entirely for reduction on the Atlantic and Gulf Coasts, yielded an estimated catch of about 1,050,000,000 pounds, the largest in the history of the fishery. Record landings of tuna on the Pacific Coast amounted to 332,000,000 pounds.

The canned pack of tuna was the largest on record. Runs of pink salmon in southeast Alaska and the supply of pilchards in California increased markedly after recent poor years. Alaska herring production was insignificant because of a price dispute. A substantial shark fishery for the vitamin-bearing livers declined by June, 1950, to a minor and unimportant level due to imports at low prices and the increased availability of synthetic vitamin A. The Pacific Northwest trawl fishery for rockfish was operating at a low level because of marketing problems. A promising shrimp fishery was discovered off Key West, Florida, and was prosecuted vigorously during the spring of 1950 by a large portion of the Gulf of Mexico and South Atlantic shrimping fleets. Catches of "trash" fish (mostly cheap or unmarketable species) mounted to large totals in New England as a source of raw material for local fish meal and fish oil plants.

Of the total catch it is estimated about one-third was used fresh or frozen, about one-third was used directly for meal, oil, and similar products, slightly less than one-third was canned, and a small amount was cured.

Interest in improved production practices continues. A large New England trawler will go to sea in July, 1950, equipped to fillet, package, and freeze its catch at sea. Loran is being used effectively by New England trawlers to pinpoint good fishing grounds. Helicopters as well as conventional planes are becoming standard accessories of California tuna clippers for locating bait and tuna. Atlantic menhaden fleets are utilizing planes as fish spotters. Both Gulf and Atlantic menhaden vessels, in an effort to cut costs, are testing Pacific Coast purse-seining methods of setting the seine directly from the vessel rather than from auxiliary boats. Steel halibut lines are in use in the Pacific Coast fishery, and nylon nets have been widely introduced for both fresh-water and marine use. A new mechanical tuna packing machine is being utilized on the Pacific Coast. Pumps are being adapted to serve in unloading the catch from fishing gear as well as from vessel holds.

Fishery products are distributed by about 3,500 wholesalers and 177,000 fish retailers. About 86 percent of the products retailed is handled by combination grocery stores. Of this 86 percent, about 55 percent is sold by chain stores.

There is continued emphasis on consumer size packages, frozen products, and specialty items. Facilities for handling frozen products both in distribution channels and in the home — through increased use of home freezer cabinets and lockers—have improved. Advertising campaigns, both local and national, have been more numerous. Sponsors include individual companies, city, state, and national trade associations, and individual states. Television advertising appears to be opening new fields.

New products on the market in appreciable volume include frozen breaded shrimp and other breaded items; film bags of salt mackerel in brine and oysters in their own liquor; canned and frozen fish frankfurters; canned fish for baby food; and canned dietetic tuna. Consideration has been given to horizontal splitting of rockfish fillets to prepare a more readily marketable product. Considerable progress has been made in introducing fishery products in the Federal School Lunch Program and in institutions by a Fish and Wildlife Service program using home economists and fishery marketing specialists.

Nearness to markets has stimulated the canning of tuna on the Atlantic Coast and aroused great interest in the Gulf of Mexico without, however, the actual establishment of canneries in that area as of September, 1950.

The Fish and Wildlife Service produced a film entitled *Food for Thought* to use in connection with its program to increase the use of fish in the school lunch program. The educational film *It's the Maine Sardine,* which was previously produced by the Service, has enjoyed extremely wide distribution throughout the current year. Another film, depicting the menhaden industry, is in production as a joint venture of the industry and the Fish and Wildlife Service. A comprehensive manual on the curing of fishery products has been sent to press. Additional results of tests of freezing fish at sea for later defrosting ashore, filleting and re-freezing continue to be promising, and the Service is expanding this research. Experiments in the use of subtilin, an antibiotic, as a preservative for fishery products are still in the earliest stages.

The three Fish and Wildlife Service research vessels based at Honolulu, Hawaii, and the new laboratory in the same place, are now in full operation on exploratory fishing, biological, and oceanographical studies. Two Fish and Wildlife Service research vessels have been assigned to the Gulf of Mexico—one vessel is already conducting exploratory fishing and gear development research, while the other will undertake biological and oceanographic programs, to begin the latter part of 1950. The newest and most modern of exploratory fishing vessels was constructed and delivered to the Service at Seattle, Washington, early in the current year and has undertaken exploratory fishing for albacore tuna in the Pacific Northwest and Alaskan waters.

Legislation has been introduced in Congress providing for voluntary inspection of frozen fishery products. Additional bills are under consideration proposing price supports, subsidies, marketing agreements, import restrictions, and similar programs such as have been in effect for agricultural products for a number of years. Also, a bill was introduced to regulate the shipment of undersized fish. Action has not been taken on any of these measures as of September, 1950.

A number of international agreements developed during the current year, which will have important bearing on the commercial fisheries, have been discussed in the Report of the Committee on International Relations.

CANADIAN FISHERIES

The catch of commercial fish in Canada during 1949 amounted to about 1.9 billion pounds, including an estimate for the Province of Newfoundland. The landed value was $70,000,000 and the estimated marketed value was $166,000,000. The catch in 1948 was taken by 94,277 fishermen—63,140 on the East Coast, 12,226 in British Columbia, and 18,911 in the inland fisheries. They used 626 fishing craft of 20 net tons or over, 1,442 from 10 to 20 tons, and 27,844 under 10 tons. The investment in fishing craft totaled $39,550,000 and in fishing gear $25,385,000. There were 19,497 persons engaged in processing fish. Of these 15,317 were on the East Coast and 4,180 in British Columbia.

The 1949 catch of the more important species was as follows:

Species	Pounds
Salmon	149,829,000
Cod	705,129,000
Herring	503,633,000
"Sardines"	62,080,000
Halibut	22,057,000
Lobster	43,269,000
Whitefish	22,020,000

In recent years the catch of herring in British Columbia has steadily increased. However, the landings in 1949 at 325 million pounds were 61 million pounds lower than in 1948. Nevertheless, the 1949 results were still very satisfactory, surpassing the prewar average (1935-39) by 164 million pounds.

Although "sardine" catch was low in 1949, the yield of this fishery substantially increased during recent years, especially from 1946 to 1948 inclusive.

Yields of other fisheries of importance have been without significant changes in the last few years, although the catch of cod reached an unusually high level in the Province of Newfoundland in 1949.

Percentage of total catch marketed in various forms (1949)

	Percent
For marketing fresh (round, dressed or fillets)	15.7
For marketing frozen (round, dressed or fillets)	14.1
For drying, salting, and smoking	40.4
For canning	9.1
For reduction to meal and oil	16.6
For other purposes, i.e., mainly bait	4.1
	100.0

Percentage of Canadian production marketed in various places

	Percent in terms of marketed value
Domestic market	33.7
United States	42.0
U. S. dependencies	3.0
United Kingdom	5.1
U. K. dependencies	4.7
Union of South Africa	.1
Other sterling countries	.3
E. R. P. countries	6.2
Latin America	4.4
All other countries	.5
	100.0

An important evolution has taken place in fishing craft on the east coast of Canada in the last decade. A fishing fleet of small and medium draggers was put into operation during the last war and has been expanded in subsequent years. Units of 20 tons and over (net registered tonnage) have almost doubled in number since 1939. The number of craft from 10 to 20 tons in size increased by 60 percent from 1939 to 1948, while the number of small boats of the inshore type decreased by 18 percent during the same period.

A change in the licensing policy for trawlers or draggers was announced by the Minister of Fisheries in December, 1949. Previously, licenses for trawlers were issued only to Canadian built ships. Under the new policy, licenses will be granted to new trawlers built in United Kingdom as well as in Canadian yards. Licenses will be issued also to better types of second-hand trawlers bought in the United Kingdom or in the United States and registered in Canada after payment of the duty. Licenses to second-hand trawlers will be granted, however, only to those who build new vessels in Canada to match the imported craft. The new policy is likely to increase the number of larger fishing units on the East Coast of Canada and stimulate the production of fresh and frozen fish.

Referring to the products being processed, in the case of herring there was a diversion in the post-war period from the canned product to the production of meal and oil. In the case of cod and related species the amount canned has also been reduced in the last 2 years and the production adjusted to meet the normal demand which, since the war and subsequent to the cessation of relief programs, is almost exclusively confined to the domestic market. The production of salted cod has been at a very high level during 1949 but difficulties were encountered in the marketing of this product due to the scarcity of dollar exchange in the Mediterranean countries, the British West Indies, and Brazil.

COMMITTEE ON NAMES OF FISHES

Reeve M. Bailey[1]

Publication in 1948 of the Society's Special Publication No. 1, *A List of Common and Scientific Names of the Better Known Fishes of the United States and Canada,* climaxed the prolonged and arduous deliberations of this committee which were conducted under the chairmanship of Walter H. Chute. Since that time the committee has been in part reorganized. Henceforth it expects to serve as a clearing house for changes and hopes to maintain the list at a maximum level of utility for all fishery workers. In so doing the committee will (1) attempt to keep the scientific nomenclature up to date; (2) accept and act on recommended additions and deletions from the list; (3) receive and judge petitions for changes of common names in the present list; and (4) prepare for republication of the list when the need arises. The committee welcomes the cooperation of the membership in the achievement of these objectives.

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[1] In the absence of the chairman, this report was presented by Ralph Hile, member of the committee.

Following the Winnipeg meeting a circular letter urged that members notify the committee about suggestions for modification of the list provided that each such requested change be accompanied by reasons for making a shift in name. We now renew the invitation.

Thus far we have received 41 requests for changes which involve 25 species. These suggestions are listed in the accompanying tabulation. Before taking final action on these requests the committee would like to receive comments from the membership. Since committee members may be unfamiliar with some of the fishes or with the commonly used vernacular names applied by sportsmen, commercial fishermen, and the trade, we enlist your assistance. Without active interest and help from the Society the committee will be ineffective.

List of species for which name changes have been suggested:

Number in list	Present Name	Proposed Substitute Name
35	MACKEREL SHARK	MAKO
109	SEBAGO SALMON	LAKE ATLANTIC SALMON, LANDLOCKED SALMON, or delete as identical with ATLANTIC SALMON
120	SHALLOWWATER CISCO	LAKE HERRING (as coequal with SHALLOWWATER CISCO)
146	RIVER CARPSUCKER	NORTHERN CARPSUCKER, or CARPSUCKER
156	RAZORBACK SUCKER	HUMPBACK SUCKER
216	PIKE	NORTHERN PIKE
226	STARHEAD TOPMINNOW	BLACKSTRIPE TOPMINNOW
227	VARIEGATED MINNOW	VARIEGATED CYPRINODON
228	DESERT MINNOW	COLORADO CYPRINODON
253	SILVER HAKE	WHITING
264	AMERICAN PLAICE	DAB
270	SUMMER FLOUNDER	FLUKE
273	FOURSPOT FLOUNDER	FOUR-SPOT
283	RUSTY DAB	YELLOWTAIL FLOUNDER
286	GEORGES BANK FLOUNDER	LEMON SOLE
289	WITCH FLOUNDER	GRAY SOLE
321	LITTLE TUNA	FALSE ALBACORE
339	DORADO	DOLPHIN
368	YELLOW PIKEPERCH	WALLEYE, DORE, or DORAY
369	BLUE PIKEPERCH	BLUE PIKE
374	SMALLMOUTH BLACK BASS	SMALLMOUTH BASS
375	SPOTTED BLACK BASS	SPOTTED BASS
376	REDEYE BLACK BASS	REDEYE BASS
377	LARGEMOUTH BLACK BASS	LARGEMOUTH BASS
422	BLUESTRIPED GRUNT	YELLOW GRUNT

MEMBERSHIP COMMITTEE

Albert S. Hazzard

No meetings of the committee were possible during the year but a membership campaign was organized by correspondence soon after appointments were announced. Each member was assigned a group of states and (or) provinces, territories, and foreign countries; where some member had special knowledge of certain groups he was asked to make a particular effort to enlist members among such groups. A letter was sent to each member suggesting a number of methods of approach which might be used in the campaign. An interim report was requested just prior to the meeting of the Executive Committee in March, 1950, at San Francisco. The results to that date were summarized and incorporated in the mid-year newsletter sent to all members of the Society by the President and Secretary.

Personal contacts were stressed in the current campaign but personal letters and even form letters were also used with considerable success. As might be expected, certain committeemen were able to devote more time and energy to the campaign than others and the results reflect these varying efforts. Also some members had more fertile fields than others in the districts assigned them and again the returns reflect these conditions.

Based on final reports received just before this meeting, some 948 contacts were made resulting in a known gain of 71 new members. Doubtless other additions to the membership should be credited to the committee's efforts since some applications were sent directly to the Secretary instead of first to the solicitor. It is generally agreed that the best way to enlarge the Society is for each member to approach his friends and acquaintances in fisheries work at every opportunity. But human nature being what it is most of us do not do this without some incentive. I feel certain that a carefully chosen membership committee will aid in the growth of the organization.

The membership as shown by the list prepared by Secretary Sprecher dated August 25, 1950, totals 1,147 members as compared with 1,038 in 1949 as given in the most recent published report (Vol. 79) of the Secretary-Treasurer. The gain in membership since last year is therefore 109, including a number of new official state memberships.

A spot map has been prepared showing the number of members in each state, province, territory, and foreign country as of August 25, 1950. This map has been photographed for permanent record and will be turned over to the next chairman of the membership committee to be brought up to date a year from now. The strength and weaknesses of the Society are evident in the figures on the map. The place and number of times annual meetings have been held in each province or state have also been shown on this map. Consideration of the present distribution of members and past places of meeting may be helpful to the committees which decide where and when our next annual gathering will occur.

EDITORIAL COMMITTEE

Lloyd L. Smith, Jr.

During the past year the Editorial Committee has been able to bring the publication of the Transactions up to date. This accomplishment has been made possible, not so much by the efforts of the incumbent editor and committee, as by Ralph Hile, the retiring editor who agreed to finish the publication of Volume 78 so that the new editor and committee could take over the job of publishing Volume 79. Now that the Transactions are again appearing on schedule, we will endeavor to bring out each succeeding volume with a minimum of delay. The greatest factor in slowing down publication is the necessity of returning manuscripts to authors for correction and revision. While a certain amount of such conference with authors will always be essential, a strict adherence by all contributors to editorial details and careful preparation of manuscripts will greatly facilitate handling by the editorial committee. In many cases critical comment by our colleagues before presentation of papers will not only help the editors immeasurably, but will improve the general quality of the contribution.

In order to facilitate the preparation of manuscripts the Editorial Committee plans to prepare a new set of editorial instructions which will be designed not only to give rules and regulations for editorial format, but will try to provide some assistance to authors, especially in the matter of preparing tables and graphs.

At the present time there appears to be a large backlog of scientific works which has not yet been put into print. Much of this material will be presented to the Society for its consideration. We can look forward to an ever-increasing amount of material and should, in the very near future, consider our editorial policy to determine the extent of our coverage in terms of both pagination and specific types of material.

The editor wishes to take this opportunity to thank all authors and others who have contributed to the preparation of Volume 79.

PROGRAM COMMITTEE

Willis King

Since the report of the Program Committee is in a sense embodied in the schedule of papers and reports to follow, it may suffice at this point for the Chairman to express his appreciation for assistance given by members of the Committee and his hope that the extent and variety of the papers presented may meet with the approval of the Society.

REPORTS OF SESSIONAL COMMITTEES

TIME AND PLACE COMMITTEE

Raymond E. Johnson

The Time and Place Committee met with the corresponding committee of the International Association of Fish, Game, and Conservation Commissioners, and it was agreed that the two societies would accept the invitation extended by the State of New York. Later the executive committees of the two societies agreed that the 1951 meetings shall be held in Rochester, New York, the American Fisheries Society sessions to be on the dates September 13-15, those of the International Association of Fish, Game, and Conservation Commissioners on September 10-11, with Wednesday, September 12, set aside for a joint field trip and the annual banquet.

Officers of the American Society of Limnology and Oceanography having expressed the interest of this group in meeting with the American Fisheries Society in 1951, the Executive Committee of the American Fisheries Society voted to extend an invitation to the American Society of Limnology and Oceanography to participate in the meetings scheduled for September 13-15.

AUDITING COMMITTEE

Andrew L. Pritchard

The Auditing Committee has examined the accounts of the American Fisheries Society for the past year and, in so far as they are able to determine, have found the statements to be accurate and correct.

The committee wishes to commend the Secretary-Treasurer and his assistants for their exemplary handling of the Society's records.

RESOLUTIONS COMMITTEE

Fred A. Westerman

1. Regional Divisions

WHEREAS, There is a movement among members of the American Fisheries Society to establish regional divisions; and

WHEREAS, It is desirable that the boundaries of such divisions be established by the parent society to insure an orderly development; now therefore

BE IT RESOLVED, That the President appoint an *ad hoc* committee to be composed of at least seven members from representative regions of the United States and Canada for the purpose of studying divisional needs and prescribing desirable boundaries for such divisions, a report to be submitted to the Society at the next annual meeting.

2. PUBLICATION OF WESTERN DIVISION PAPERS

WHEREAS, Papers presented at the meetings of the Western Division have not been published in the TRANSACTIONS of the Society; and

WHEREAS, Important papers should be recorded there in the interest of disseminating information and maintaining a cohesive organization; now therefore

BE IT RESOLVED, That the members of the Western Division and the members of any other division that may subsequently be organized be encouraged to submit their papers in proper form to the Editorial Committee, and that the Editorial Committee give these papers consideration for publication in the same sense as papers presented at the annual meeting of the Society.

3. PUBLICATIONS OF THE AMERICAN FISHERIES SOCIETY

WHEREAS, The present annual TRANSACTIONS are insufficient to provide for the publication of all worthy technical papers presented for publication; and

WHEREAS, The trend toward divisional organizations encourages, and should encourage, the publication of regional problems; and

WHEREAS, The financial status of the Society appears adequate; now therefore

BE IT RESOLVED, That the President appoint an *ad hoc* committee to consider the publication of a periodical journal, such journal to include regional and special technical problems, allowing maximum space in the annual TRANSACTIONS for problems having international and general application; a report to be submitted to the Society at the next annual meeting.

4. FEDERAL AID TO STATE FISHERIES

WHEREAS, The American Fisheries Society has upon several occasions, in meeting assembled, urged the enactment of congressional legislation to provide federal aid to state fisheries comparable to the Federal Aid in Wildlife Restoration (Pittman-Robertson) Act; and

WHEREAS, Public Law 681, commonly known as the Dingell-Johnson Bill, was passed by the 81st Congress and signed by President Truman; now therefore

BE IT RESOLVED, That the American Fisheries Society commend the 81st Congress of the United States and the President on their passage of this bill.

5. Ice Harbor and Three Other Proposed Dams in the Lower Snake River

WHEREAS, The most valuable races of Columbia River salmon inhabit the Snake River and tributaries upstream from Ice Harbor and three other authorized dams on the lower Snake River; and

WHEREAS, It is the opinion of fishery biologists that these four proposed dams would seriously jeopardize the salmon runs with a market value of approximately $8,000,000 annually and constituting half of the total Columbia River salmon fishery; and

WHEREAS, The power to be developed from all four of the authorized dams does not equal the power potential at McNary or at Chief Joseph nor at certain other main stream sites on the Columbia River which would do considerably less damage to fishery and recreational values; and

WHEREAS, Flood control, irrigation and navigation benefits from these four proposed dams are not of great significance; now therefore

BE IT RESOLVED, That the American Fisheries Society strongly opposes construction of Ice Harbor Dam and the three other lower Snake River dams.

6. Committee on Employment and Professional Standards

WHEREAS, There is a need for a strengthening of professional standards in the fisheries field; and

WHEREAS, The American Fisheries Society is the logical organization to set up a Committee on Employment and Professional Standards in Fisheries Biology and Management; and

WHEREAS, The problems which would come to such a committee are being greatly increased by the Dingell-Johnson Bill and by the multiplication of schools giving course work in the fisheries field; now therefore

BE IT RESOLVED, That the President appoint an *ad hoc* Committee on Employment and Professional Standards of from 5 to 8 members;

That this Committee, in the near future, make a survey of the employment situation and prepare, in so far as possible, a guide to Professional Standards, for use by employing and training agencies;

That the Committee be authorized to publish newsletter summaries of the employment picture at intervals to be sent by the Secretary to all members of the Society; and

That an amendment to the By-Laws be instigated to place this committee on a permanent standing committee basis.

7. POLLUTION ABATEMENT

WHEREAS, The abatement of pollution of our natural waters is a means of improving and increasing suitable fish and wildlife habitat; and

WHEREAS, Public Law 845 takes national cognizance of the pollution situation as a result of the activity of interested sportsmen, fisheries, and public health groups; and

WHEREAS, The condition of the habitat of our fish population is properly a consideration of the American Fisheries Society; now therefore

BE IT RESOLVED, That an *ad hoc* committee of not less than 5 members be appointed to report to the Society at the next annual meeting on the progress made in pollution abatement, and to acquaint the appropriate agencies that the American Fisheries Society is deeply concerned with the elimination and prevention of pollution of our waters; also

That an amendment to the By-Laws be instigated to place this committee on a permanent standing committee basis.

8. SPORT FISHING INSTITUTE

WHEREAS, There was incorporated in Washington, D. C., in October of 1949, a non-profit organization known as the Sport Fishing Institute; and

WHEREAS, The attested objective of this new organization is the improvement of sport fishing in America; now therefore

BE IT RESOLVED, That the American Fisheries Society extend felicitations and approbation to the Sport Fishing Institute on its establishment and purpose.

9. APPRECIATION OF HOSPITALITY

WHEREAS, The Society has been extended unexcelled privileges and has been entertained graciously at its 80th Annual Meeting in Memphis, Tennessee; and

WHEREAS, The members and guests have enjoyed extraordinary courtesies; now therefore

BE IT RESOLVED, That the American Fisheries Society express its sincere appreciation and profound gratitude to the State of Tennessee, the Tennessee State Game and Fish Commission, the Tennessee Department of Conservation, the Memphis Chamber of Commerce, the Memphis Ladies' Committee, the Tennessee Conservation League, the West Tennessee Sportsman's Association, and all of the other organizations and individuals whose efforts contributed to the success of the meeting. The Society also wishes to thank the local committees, formed especially for this occasion, and the management of the Peabody Hotel for so ably demonstrating the renowned hospitality of the citizens of Memphis.

NOMINATING COMMITTEE

Capt. C. F. Culler

The Nominating Committee submitted the following list of names of members to serve as officers of the Society:

President	Albert S. Hazzard, Michigan
First Vice-President	A. H. Wiebe, Tennessee
Second Vice-President	W. J. K. Harkness, Ontario
Secretary-Treasurer	G. E. Sprecher, Wisconsin
Librarian	W. C. Beckman, Colorado

From the floor, Dr. Ralph Hile was nominated for the office of First Vice-President. In subsequent balloting neither candidate obtained the two-thirds majority required by the Constitution. The Chair accordingly declared both nominations void, and called for new nominations from the floor for the office of First Vice-President. Dr. W. J. K. Harkness was nominated and approved without dissent. The Chair then called for nominations from the floor for the office of Second Vice-President. Dr. Ralph Hile was nominated and approved without dissent. The nominations of the Nominating Committee for President, Secretary-Treasurer, and Librarian were approved without dissent, as were all choices of the Nominating Committee for elective committee positions.

The slate of officers and committeemen adopted by the Society follows:

Officers

President	Albert S. Hazzard, Michigan
First Vice-President	W. J. K. Harkness, Ontario
Second Vice-President	Ralph Hile, Michigan
Secretary-Treasurer	G. E. Sprecher, Wisconsin
Librarian	W. C. Beckman, Colorado

COMMITTEE ON INTERNATIONAL RELATIONS

A. L. Pritchard, Ontario, *Chairman*
A. G. Hunstman, Ontario
Donald L. McKernan, Oregon
Fernando Obregon, Mexico
W. C. Senning, New York
Marion Toole, Texas
John Van Oosten, Michigan

COMMITTEE ON NATIONAL-STATE RELATIONS

Fred Thompson, New Mexico, *Chairman*
E. J. Douglass, District of Columbia
R. W. Eschmeyer, District of Columbia
H. R. Morgan, North Dakota
E. F. Swift, Wisconsin

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

Edward Schneberger, Wisconsin, *Chairman*
John F. Dequine, Florida
F. E. J. Fry, Ontario
O. R. Kingsbury, New York
James W. Moffett, Michigan
Clarence F. Pautzke, Washington
Seth Way, Kansas

COMMITTEE ON COMMERCIAL FISHERIES

Richard S. Croker, California, *Chairman*
Howard K. Balch, Wisconsin
J. N. Gowanloch, Louisiana
John L. Hart, British Columbia
R. A. McKenzie, New Brunswick
W. J. I. Purvis, Ontario
R. V. Truitt, Maryland

COMMITTEE ON NAMES OF FISHES

Reeve M. Bailey, Michigan, *Chairman*
W. A. Clemens, British Columbia
J. R. Dymond, Ontario
Raymond E. Johnson, Minnesota
George S. Myers, California
Edward C. Raney, New York
Leonard P. Schultz, District of Columbia

CONCLUDING BUSINESS

The Retiring President: The next order of business is the installation of newly elected officers. Before turning over the gavel to the new President I should like to thank the officers and committees who have served with me during the past year, and to urge for our successors the same generous support from the Society that we have enjoyed.

I now ask that Mr. E. L. Wickliff, of Ohio, and Dr. Edward Schneberger, of Wisconsin, escort Dr. Albert S. Hazzard, of Michigan, the new President, to the Chair. [Applause.]

The New President: Thank you, gentlemen. Mr. James, members of the Society and guests—I deeply appreciate the honor you have conferred upon me.

In view of the times we live in, it is impossible not to feel some concern for the future of the Society. Yet, I can remember problems which were surmounted in the past, and which at the time seemed at least as grave as those now confronting us. I know, from the list of officers and committeemen you have elected tonight, that I will have capable help in the coming year. And I am sure that we can depend upon the continued loyal support of the membership.

It is the first duty of a newly elected President to make appointments to certain committees. I am pleased to announce that Dr. Lloyd L. Smith, Jr. has consented to continue as Chairman of the Editorial Committee, or Editor. To fill two vacancies on this committee I appoint, as Associate Editors, Dr. Justin W. Leonard of Michigan, to succeed himself, and Dr. Raymond E. Johnson of Minnesota, to succeed Mr. K. G. Fukano.

Resolutions adopted by the Society at this meeting instruct the President to appoint four *ad hoc* committees. These committees, and members hereby appointed to serve on them, are as follows:

Committee on Regional Divisions

George W. Bennett, Illinois, *Chairman*
George W. Davis, Vermont
John F. Dequine, Florida
Kenneth H. Doan, Manitoba
Willis King, Tennessee
Charles N. Lloyd, Wisconsin
Gustave Prevost, Quebec
James C. Simpson, Idaho

COMMITTEE ON PUBLICATION OF A PERIODICAL JOURNAL

Ralph Hile, Michigan, *Chairman*
William C. Beckman, Colorado
A. G. Hunstman, Ontario
Edward C. Raney, New York
Lloyd L. Smith, Jr., Minnesota
A. V. Tunison, District of Columbia
Boyd W. Walker, California

COMMITTEE ON EMPLOYMENT AND PROFESSIONAL STANDARDS

Thomas H. Langlois, Ohio, *Chairman*
Clinton L. Baker, Tennessee
Kenneth D. Carlander, Iowa
John R. Greeley, New York
Elmer Higgins, District of Columbia
Justin W. Leonard, Michigan
M. W. Smith, New Brunswick
William F. Thompson, Washington

COMMITTEE ON POLLUTION ABATEMENT

Clarence M. Tarzwell, Ohio, *Chairman*
Robert O. Beatty, Illinois
H. Wesley Curran, Quebec
Cecil Heacox, New York
Frank T. Knapp, Texas
Leo Shapovalov, California
Willis M. Van Horn, Wisconsin

There being no further business for consideration at this time, a motion for adjournment is in order.

The Eightieth Annual Meeting of the American Fisheries Society was adjourned.

Appendices

INSTRUCTIONS FOR PREPARING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1951)

Please check each item below before the final typing of your manuscript and help your Society reduce the costs of publication, save your Editorial Board (which works gratis) much needless work, time, and expense, and avoid delay in the publication of the *Transactions*.

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals (Government Printing Office Style Manual; University of Chicago Style Manual). Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. MANUSCRIPT MUST BE TYPEWRITTEN DOUBLE-SPACED, including titles, headings, legends for tables and illustrations, and literature citations. Use one side only of sheet. Do not fold manuscript. Write manuscript only in simple upper and lower case. DO NOT USE ALL CAPITAL LETTERS FOR ANY PURPOSE AND UNDERSCORE ONLY WHERE ITALICS ARE INTENDED. NO MANUSCRIPT WILL BE ACCEPTED UNLESS IT CONFORMS TO THIS STYLE.

2. CARBON COPIES WILL NOT BE ACCEPTED. Do not use thin, transparent paper. Heavy bond paper is preferred.

3. MARGINS at top, bottom, and both sides must be no less than 1¼ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. PAGES must be numbered in consecutive order, including the literature cited, tables, charts, and photographs. Tables and legends of charts and illustrations must be inserted near their place of reference in the text.

5. ILLUSTRATIONS. Make separate pages of tables with headings (not of leader work), of legends of diagrams, charts, and illustrations, and limit the number to those absolutely necessary to clarify or supplement text. *Tables and cuts cost money!* Only sharp, glossy photos can be used. All drawings, charts, and diagrams should be prepared in waterproof India ink on Bristol Board, other perfectly smooth white paper or cardboard, or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the shading lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed 4¼ by 6½ inches (inclusive of legends) when reduced. All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend. The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, charts, and tables, and with Arabic, not Roman, numerals.

6. FOOTNOTES in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by

two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1.

7. The title of the manuscript, together with the author's name (write out in full either one or both of the Christian names and do not use "by"), position or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

REPORT ON THE DISEASES OF BROOK TROUT

John Edward Doe
Department of Conservation, Lansing, Michigan

8. Underscore (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius. Do not underscore any words unless italics are intended.*

9. Inspect papers in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. Bibliographic references in text should give name of author and year of publication in parentheses, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below to be placed at end of paper:

Literature Cited

Doe, John C., J. W. Brown, and H. W. Green
1939. Report on the diseases of brook trout. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 450-461.

Note that the year of publication precedes the title and the year of the meeting is stated in the reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and very inaccurate. Help us correct this situation.

11. Tables. Every table should have a heading and must be typewritten on a separate page. Insert tables among the text pages near the points where they are

Item	Number of fish	Percentage of total	Average length millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.25

discussed. In preparing tables please be certain that they are not too large to appear on a single printed page. Number tables consecutively with Arabic, not Roman, numerals (1, 2, 3, etc.). Abbreviate the word "number" (No.) when referring to a special number—not when referring to quantity or things. Spell all other words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date*, in body of table), and capitalize, as a rule, the first word only in headings in the 1st column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

12. CAPITALS. Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to a particular State, Government, and to organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Hoover Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. ABBREVIATIONS.

(a) Abbreviate the following:
Clock time, if connected with figures—2:30 a.m.
Temperatures, F. (Fahrenheit).
Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.
Number, if preceding figures—No. 125; otherwise spell out.
United States, if preceding name of a department or a bureau of a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana*.
Months, in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:
States, cities, etc.
Months, in text or in headings of tables—April 5-September 2.
Measures and weight, except p.p.m., 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.
Percentage, 12 percent, a percentage of 25.5.

14. NUMERALS. Spell out all *isolated* numbers less than 10, but use figures in a group of enumerations when any one number of that group is 10 or greater. Do not spell out numbers of two or more digits (except round numbers of approximations: estimated at five hundred; a thousand fish), and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were nine trout. There were 9 trout, 120 bass, and 50 pike.

Use figures for all enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth inch). For example: $3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; the 1st of January, 1938; the 20th day of March; 1937-38; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch trout; 120 6-inch trout.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

Spell out such indefinite expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout.

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. USE OF HYPHEN. Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentence: "This species is adapted to *"cold water."* "Trout are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

Write "largemouth" and "smallmouth" as one word when referring to black bass.

III. SUBJECT MATTER

16. CONDENSE YOUR PAPER to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. PAPERS WHICH ARE TOO POORLY WRITTEN WILL BE REJECTED.

17. BE DEFINITE IN REFERENCES TO SPECIES. The scientific name, and wherever needed the *complete* common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "bass," trout," and "pickerel" apply to any one of several species. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth black bass," "brook trout," "rainbow trout," etc.

18. THINGS TO AVOID. Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "show," "found," "gave," and "present" are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives*. Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: *"This* was true in every *case."* *"The mortality* was *high* in every *pond."*

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. ABSTRACT OF PAPER. Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

Prepared by the Editorial Board
February, 1937 (revised 1950)

AMERICAN FISHERIES SOCIETY

LIST OF MEMBERS

Compiled June 1, 1951

HONORARY MEMBERS

The President of the United States.
The President of Mexico.
The Secretary of the Interior of the United States.
The Governors of the several States.
The Governor-General of Canada.
The Lieutenant-Governor of the several Canadian Provinces.
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